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ABSTRACT

These proceedings of the conference's Special Sessions contain 85 papers organized into the following sections: "Implant Materials and Devices," "Communication Aids," "Neural Prosthetics for the Disabled," "Current Concepts in Spinal Cord Rehabilitation," "New Models in Rehabilitation," "Communication Aids for the Hearing Impaired," "Vocational Rehabilitation," "Prosthetics and Orthotics," "Blind, Visually Impaired," and "Adaptive Aids." Included are the following papers: "Engineering Design of Implant Systems" (G. McNeice); "Communication Interaction Between Aid Users and Natural Speakers--An International Perspective" (A. Kraat); "Electrical Control of Bladder Function in the Paralyzed" (A. Talalla and J. Bloom); "Biomechanics of Spinal Reconstruction" (R. Whitehill); "Transcendence Towards an Ethics of Rehabilitation" (D. Roy); "Coding of Speech in Cochlear Implants" (M. Merzenich); "Employing Severely Disabled Persons in Computer-Related Fields" (C. Warren); "Linking Rehabilitation Technology to Rehabilitation Service Delivery" (C. Whitcraft and C. Laenger, Sr.); "The Use of Electrical Stimulation for the Treatment of Scoliosis in Children" (M. Herbert); "Technological Change and Employment of Blind and Visually Impaired People" (F. Schmidt); "Questionable Devices" (A. Enders); and "Implications of the Environment for Persons with Disabilities" (P. Cluff). (JDD)

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SECOND INTERNATIONAL CONFERENCE ON REHABILITATION ENGINEERING

JUNE/JUIN 17-22, 1984 **OTTAWA, CANADA**

DEUXIÈME CONFÉRENCE INTERNATIONALE SUR LA TECHNOLOGIE DE RÉÉDUCATION FONCTIONNELLE

EU AUTRES

combined with the

RESNA 7th ANNUAL CONFERENCE

tenue parallèlement à la

RESNA 7e CONFÉRENCE ANNUELLE

SECOND INTERNATIONAL CONFERENCE ON REHABILITATION ENGINEERING
Combined with the RESNA 7th ANNUAL CONFERENCE

SPECIAL SESSIONS

SÉANCES SPÉCIALES

DEUXIÈME CONFÉRENCE INTERNATIONALE SUR LA TECHNOLOGIE
DE RÉÉDUCATION FONCTIONNELLE
Tenue parallèlement à la RESNA 7e CONFÉRENCE ANNUELLE

OTTAWA, CANADA
17–22 June/juin 1984

Special Sessions
Second International Conference on Rehabilitation Engineering
combined with the
RESNA Seventh Annual Conference
Ottawa, Canada, June 17-22, 1984

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MARION DEWAR

MAYOR MAIRE

June 1984.
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On behalf of the citizens and Council of the City of Ottawa, I am pleased to welcome you to the Second International Conference on Rehabilitation Engineering and the Seventh Annual Conference on Rehabilitation Engineering, and to the National Capital.

Au nom de la population et du Conseil municipal d'Ottawa, je suis heureuse de vous souhaiter la bienvenue à la Deuxième conférence internationale sur la technologie de rééducation fonctionnelle, à la 7e conférence sur la technologie de rééducation fonctionnelle et à la capitale nationale.

We were delighted to have you among us, and hope that despite your busy agenda you will have an opportunity to renew old friendships and form new ones during your stay.

Nous sommes heureux de vous accueillir parmi nous et espérons que malgré votre programme chargé vous profiterez de l'occasion pour renouveler d'anciennes amitiés et en nouer de nouvelles durant votre séjour.

I hope as well that you will have the time to explore our City, to discover the many cultural and recreational facilities available to you, and to experience first hand the warmth and hospitality of our citizens.

J'espère également que vous prendrez le temps de visiter notre ville, d'en découvrir les maintes installations culturelles et récréatives et que vous goûterez personnellement l'hospitalité chaleureuse de nos citoyens.

I extend to you my best wishes for a successful conference, and my warm welcome to our City.

Agréez mes meilleurs voeux de succès dans vos délibérations et un chaleureux accueil à Ottawa.

Marion Dewar
Mayor/Maire

PREFACE

We have been fortunate to have been able to organize ten special sessions for ICRE II. The sessions address topics of particular interest to those who are concerned with habilitation/rehabilitation. The volume represents the efforts of ninety invited speakers and state of the art presentations. The speakers come from a variety of backgrounds and therefore address the issues from differing perspectives. It is these different perspectives which add to the interest and value of this publication.

O.Z. Roy and R. Foulds
Co-Chairmen, ICRE II

AVANT-PROPOS

Nous avons eu la chance de pouvoir organiser dix séances spéciales dans le cadre de la ICRE II. Ces séances portent sur des sujets intéressant particulièrement tous ceux qui oeuvrent dans le domaine de l'adaptation et la réadaptation. Le volume représente les efforts de quatre-vingt-dix conférenciers invités et contient les exposés de l'état des connaissances en la matière. Les conférenciers proviennent de milieux divers et abordent donc le sujet de points de vue différents. C'est justement cette divergence des points de vue qui ajoute à l'intérêt et à la valeur de cette publication.

Les co-présidents, ICRE II

O.Z. Roy et R. Foulds

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IMPLANT MATERIALS AND DEVICES/

BIOMATÉRIAUX, ORGANES ARTIFICIELS ET DISPOSITIFS IMPLANTÉS

Co-chairpersons/Co-présidents:

G. Drouin
Institut de réadaptation de Montréal
Montréal, Canada

R.M. Pilliar
University of Toronto
Toronto, Canada

ORTHOPAEDIC IMPLANTS AND DEVICES, AN OVERVIEW - STATE OF THE ART AND FUTURE TRENDS

I.J. Harrington, M.D.
Toronto East General and Orthopaedic Hospital Inc., 825 Coxwell Avenue, Toronto, Ontario
M4C 3E7

ABSTRACT - A historical review of orthopaedic implant development is presented. Current design problems, particularly those related to device fixation, are discussed. Some new trends in prosthetic designs are outlined.

RÉSUMÉ - L'auteur présente un examen historique du développement des implants orhtopédiques. Il étudie les problèmes de conception actuels, notamment ceux qui concernent la fixation des appareils. Enfin, quelques tendances nouvelles dans le domaine des prothèses sont décrites.

HISTORICAL REVIEW:

Much of the early work on implants has been carried out within the field of orthopaedics and limited primarily to the use of internal appliances to secure fractured segments of bone. A variety of metals were used with early internal fixation devices, including aluminium, silver, brass, and copper. It became apparent that mixed metals, as plate-screw combinations, rapidly caused disintegration of bone due to their electrolytic action in body fluids. The introduction of corrosion resistant stainless steel in 1926 was perhaps the most significant development in fracture surgery. The treatment of hip fractures, for example, prior to the development of stainless steel, was crude and risky from the standpoint of infection created by highly corrosive implants. Consequently, the most common method of treatment was to use a body cast to hold the hip in position while the fracture healed.

The introduction of a stainless steel triflanged nail by Smith-Petersen in 1925, combined with a side-plate developed by Thornton in 1937, revolutionized the treatment of hip fractures, and provided the prototype for most of the orthopaedic devices used in hip fracture treatment today. Smith-Petersen was also instrumental in the early development of hip arthroplasty. He inserted a cup between the acetabulum and the head of the femur, theorizing that a new joint could be regenerated by the body if the implant acted as a mold. Mold arthroplasty has been performed with varying degrees of success and is the forerunner of the modern surface replacement hip arthroplasty. Hey-Groves studied various arthroplasty techniques, including a replacement of the femoral head with an ivory prosthesis in 1926. The earlies total hip replacement was devised by Wiles in 1938, using a prosthetic acetabulum and a new femoral head perched on the end of a bolt inserted through the neck of the femur. In 1946, the Judet Brothers designed the first femoral prosthesis, utilizing bio-mechanical principles. Their prosthesis was the first mass produced surgical implant to use acrylic. The acrylic, however, was too brittle to withstand the high loads transmitted at the hip and failed frequently with spalling of the articular surface and also from fracture of the acrylic stem.

Moore, in 1959, and Thompson in 1954, introduced femoral head replacement prostheses. These were similar in many respects and constructed of cast cobalt chromium alloy. Both possessed stems which were inserted into the shaft of the femur. The Moore prosthesis stem was fenestrated in order to encourage fixation by bone ingrowth. The Thompson prosthesis was designed with a plain stem to allow easier extraction if there were problems. In many respects, current developments in hip arthroplasties follow the same design criteria - it is important to devise a prosthesis that can be rigidly fixed to bone but on the other hand, does not present a problem should extraction become necessary. Both the Moore and Thompson prosthesis continue to be used today inspite of newer designs. Because of their relatively large size, mechanical failures do not occur. Their design is simple and corrosion is not a problem. Because both prostheses have large femoral head diameters, they tend to produce high frictional torque at the bearing interface causing penetration and migration of the

prosthesis into the pelvis. Loosening of the femoral stem can also occur.

It was not until 1951 that McKee inserted an all stainless steel total hip. Other designs followed with the development of the Charnley prosthesis in 1957 which used a stainless steel teflon bearing combination, later changed to stainless steel and polyethylene. The revolutionary innovation was the use of acrylic as a grouting agent for implant fixation by Charnley and Smith. The success of the Charnley total hip prosthesis is due, in part, to the excellent bond which can be obtained between the prosthetic components and bone. Newer bonding techniques, including pressure injection of low viscosity acrylic cement and the use of porous coated materials for bone ingrowth, for the most part remain experimental. Whatever method of fixation is used, it must be maintained under extremes of applied load.

Although the hip historically has received the greatest attention, it is not the only joint in the body to be affected by disease, nor the only one where replacement by a prosthesis is possible. The shoulder, elbow, hand, knee and ankle have all been subjected to various degrees of arthroplasty. The historical development of arthroplasty of the knee has generally followed the pattern of resection, arthrolysis, interposition, and more recently, total replacement of the joint. Ferguson, in 1861, was the first to obtain a moveable and functioning knee joint following resection. Verneuil (1860) was the first to suggest interposition of tissues between the resected surfaces of joints to prevent them from becoming adherent. Many materials, both organic and inorganic, have been tested with varying degrees of success since Verneuil's first attempts. Gluck (1902) used skin to fashion a dermis arthroplasty of the knee. This idea was revised by Kallio (1956) and later by Simmons and Murray (1957). Arthroplasty of the knee, using artificial materials, has tended to parallel that of the hip. Endoprostheses constructed as hinge joints with replacement of both the femoral and tibial components were inserted in the knee by Waldius (1953) and Shiers (1954). The most recent contribution to the development of a total knee joint prosthesis has been that of Gunston in 1970. The concept of using a metal femoral component articulating with a polyethylene tibial condyle has gained acceptance by the orthopaedic community. A variety of so-called surface replacement designs of the semi-constrained and unconstrained varieties are now available.

STATE OF THE ART:

Fixation

The success of any orthopaedic implant depends on the rigidity of fixation. This is especially true of joint replacement arthroplasty involving weight bearing joints. The knee particularly presents a special problem. Most current bio-mechanical research is designed to determine and prevent the causes of loosening of knee replacement devices. Loosening of the tibial component presents special problems and in some series, accounts for 20 percent of prosthetic failures. This was especially evident in the early designs. The problem is less critical at the hip but loosening, particularly of the acetabular component continues to occur. This was predicted by Charnley in his initial work where he emphasized the importance of frictional torque transmitted by the prosthetic components to bone. Maintaining a small diameter femoral head and a low co-efficient of friction between articulating bearing materials was stressed by Charnley as the most important parameters for maintaining low frictional torque and thereby lessening the chances of prosthetic loosening. Loosening of the femoral component and fracturing of the metal stem are less common phenomena and have been attributed, by Charnley and others, to poor cementing technique and/or the use of a thin or small stemmed metal prostheses, especially in overweight patients. Stem fractures no longer seem to be a problem with the advent of newer designs which are bulkier and have cross-sectional shapes designed to lessen stress formation in the implant and at the metal cement and cement bone interface.

The methods of implant fixation which are currently in use involve screw fixation, friction fit whereby the femoral component is "jammed" into the medullary canal, grouting with regular simplex polymethylmethacrylate cement as advocated by Charnley, pressure injection of low viscosity cement utilizing the principles and techniques described by Miller et al, porous surface coating of implants and most recently, the use of an iso elastic prosthesis - a rigid metal femoral component coated with a deformable elastic material such as polyethylene. The isoelastic prosthesis utilizes the bio-mechanical principle that deformation of the plastic surface coating will enhance fixation but decrease stress concentration at the implant bone interface, thereby lessening the chance of loosening and pressure induced osteonecrosis.

A paradox remains. It is important to design a prosthesis that is rigidly fixed to bone in order to minimize the likelihood of loosening but it is also important that fixation not be so rigid that removal of the implant is impossible when problems occur. To date, the paradox remains unresolved.

It has also become obvious that with bone ingrowth into porous coated surfaces, fixation becomes so rigid that stress relief occurs. This is particularly evident at the upper end of the femur. Most of the work to date has been done in experimental animals and from these studies, it is evident that osteolysis of bone develops in accordance with Wolf's law. To date, limited information regarding this phenomena is available in humans but osteolysis of the upper femur has been observed clinically following the use of

porous coated replacement prostheses, both at the hip and knee. It is of interest that newer prosthetic designs which only partially coat the prosthesis with a porous surface are being developed in an attempt to modify the stress relieving effect of total porous coating.

There is no doubt that low viscosity cement, utilizing pressure injection techniques, enhances fixation. Fixation, however, may be of limited duration since the affect of pressure injection on bone viability at the interface remains unknown. It is possible that the late effect of this method of fixation may, in fact, result in increased incidences of prosthetic loosening. Further experimental work is required in this area.

Infection

Infection is the main clinical concern in orthopaedic surgery regardless of the type of implant used. With the advent of non-corrosive arthroplasty materials, the incidence has been lessened; nevertheless, it remains a potential hazard and when it occurs, it is a disaster. The risks of infection have been reduced considerably by the use of antibiotics before, during and after surgery, meticulous surgical technique, and a clean air environment. Aggressive treatment of existing infection may salvage some implants.

Materials

Stainless steel, chrome cobalt molybdenum alloys and titanium are the metals used dominantly in current joint arthroplasties. Polyethylene, either of low or high density molecular structure, occasionally surface hardened for increased wear resistance, is the plastic arthroplasty material of choice. Regular polymethylmethacrylate or low viscosity acrylic cement continues to be used as the grouting agent for prosthetic component fixation. Attempts to improve the mechanical properties of the acrylic with the addition of various reinforcing materials; e.g. carbon, etc., to date, have not found universal clinical use. Mechanically, polymethylmethacrylate functions best under conditions of compression and should be used where possible in this loading situation.

Prosthetic Design

Contemporary hip and knee prostheses are designed to modify stress transmission through the prosthesis and at the prosthetic cement bone interface.

At the hip, this is accomplished by reducing frictional torque, primarily by minimizing the femoral head diameter and using bearing materials with a low co-efficient of friction. The role of acetabular cup thickness is unresolved. A thick walled design probably reduces stress transmission at the implant bone interface, thereby lessening the possibility of loosening. Femoral stem shape undoubtedly affects cement fixation due to the wedge effect described by Charnley. The cross-sectional shape of the stem and its size determines the resistance to bending and, therefore, stem fracture. Varus-valgus alignment of the femoral neck, medialization of the cup, and transplantation of the trochanter, all affect load transmission via the prosthesis, by decreasing the applied bending moment.

At the knee, force transmission depends on whether the knee implant is constrained or unconstrained. Constrained prostheses, using stems, have limited use because of their bulk, limited range of movement, and a tendency to loosen as well as damage the supporting bone stock. The difficulty of combining stability and joint movement has, for the most part, been resolved with current surface replacement designs which do not employ intramedullary stems. Stability is achieved, utilizing the principles of adjusting soft tissue tension in the supporting ligaments and by designing congruent bearing surfaces. Loosening of the polyethylene tibial component in knee arthroplasty, however, remains a problem. Attempts to enhance fixation employing low viscosity pressure injection techniques and porous coated prostheses are now in vogue. Injection of low viscosity cement through injection ports with the prostheses mounted on prepared bone surfaces may further enhance fixation. All of these methods require meticulous exacting surgical technique and, at this point, are probably best considered as experimental.

Future Trends

It is difficult to predict with any accuracy what future prosthetic designs will involve. It is evident, however,that in the short term, newer techniques will be devised to enhance fixation and reduce stress distribution at the implant and implant bone interface. The new Charnley hip prosthesis illustrates some of the newer trends whereby pressure injection of the acetabular component is enhanced using a peripheral flange, along with better design and fixation of the femoral component. There is little doubt that improved geometric design, particularly of the knee, will reduce stress distribution at the prosthetic interface, thereby lessening the chance of mechanical failure and reducing the amount of wear. The various parameters which affect component loosening are not clearly understood. Much of the basic knowledge related to joint kinematics and joint force transmission remains empirical. Detailed studies in these areas are necessary so that pre-implant testing devices, such as joint simulators, can be used prior to clinical implantation of prostheses in order to eliminate poor arthroplasty design. At the present time, a trial and error approach is used on a clinical basis to determine which designs have merit. This is clearly not acceptable. Many of the past

failures, due to the application of faulty biomechanical principles, e.g. the Judet prosthesis, could have been predicted if simulated joint testing were available.

New materials will likely be developed that have properties similar to biological tissues so that coating or replacement of the articular cartilage, without excision of the joint, will be possible. Salter has shown that continuous passive motion stimulates cartilage regeneration at the bearing surface. Salter's technique, in combination with surgical methods to reshape and restore the geometry of the bearing surfaces, may be a biological alternative to complete replacement of the joint with inorganic materials. Isoelastic designs may replace acrylic cement and porous coating as a method of femoral component implant fixation. There may also be a role for the use of artificial ligaments in knee arthroplasty.

Regardless of future design and material developments, it is likely that the next generation of implant surgeons must be well grounded in engineering techniques. Although the classic qualities of a surgeon with regards to handling of tissues will continue to be important, the future of arthroplasty surgery will depend almost entirely on the application of engineering principles by the operating surgeon.

IN-VIVO STRAIN MEASUREMENTS

R.H. Brown and D.T. Davy
Case Western Reserve University, Cleveland, U.S.A. 44106

ABSTRACT - This paper reviews the methods by which direct in vivo force measurements are made and the importance of these measurements to the development of implanted orthopaedic devices.

RÉSUMÉ - Le présent mémoire passe en revue les méthodes selon lesquelles les mesures directes des contraintes in vivo sont effectuées, de même que l'importance de ces mesures dans la mise au point de dispositifs orthopédiques implantés.

INTRODUCTION

For over a century now load-carying implants have been in use in Orthopaedics. In spite of this long history virtually all the knowledge regarding the loads borne by these implants results from calculations based on kinematic measurements, body weights and geometries and external force measurements. That this approach has been less than satisfactory is demonstrated by the fact that many implant failures are still being reported in the current literature. If continued development of these devices is to be rationally pursued it is necessary that we increase our knowledge regarding the forces these implants are subjected to in-vivo. This knowledge will not only allow us to fabricate better implants but will also aid us in the appropriate choice of a specific implant for a given situation.

To date only four direct in-vivo experimental measurements of loads born on an orthopaedic implant have been reported. Rydell (1966) inserted an instrumented femoral head prosthesis, similar to the Austin-Moore replacement, to treat a fracture of the femoral neck. In his design, strain gages were mounted within the neck of the prosthesis. At the time of surgery, the strain gage leads were left in a subcutaneous location. Six months after the insertion of the prosthesis, these wires were exposed through a short incision. Over 40 hours in-vivo load measurements were recorded as the patient performed a series of exercises. Rydell correlated his in-vivo force readings with force plate measurements. While Rydell found the patterns of loading were similar to those predicted by dynamic analysis technique, the magnitude of the measured loads were on the lower end of most previous researcher predictions. Paul's (1967) calculations derived from kinematic and force plate data, indicated that femoral head loads during walking in an active male should be from 5 to 7 times body weight. However, Rydell's data from the instrumented prosthesis indicated levels generally not more than approximately 3 times body weight.

Nachemson (1971) utilized telemetry to determine the loads on Harrington rods after implantantation in scoliotic patients. At the time of his investigation, the standard surgical treatment of scoliosis in Sweden consisted of a two-stage procedure. The first procedure was a ligamentous soft tissue release around the spine concomitant with distraction using Harrington instrumentation. A two week interim was then allowed for soft tissue relaxation to occur prior to the second surgery when the actual fusion was performed. Because of this surgical technique, Nachemson was able to utilize a rather bulky two part implant to telemeter loading data on the Harrington rod between the first and second procedures. While this investigation yielded important data concerning the immediate post-operative management of patients with Harrington instrumentation, the telemeterized implant was removed during the second procedure precluding obtaining any long term data.

English and Kilvington (1979) reported the development and the implantation in one patient of a telemeterized hip prosthesis instrumented similarly to the prosthesis of Rydell with an encapsulated transmitter and batteries implanted in the subcutaneous fat tissue. They reported data for up to 42 days showing a peak hip load of approximately 2.7 times body weight during a gait cycle.

Brown et.al. (1982) reported on a system of multi-channel telemetry capable of broadcasting in-vivo loading from orthopaedic implants. A series of five patients who were treated with the instrumented nail plate for stabilization of femoral fractures or osteotomies were reported. Of the five telemetered hip nails implanted, three produced clinically significant results which will be discussed subsequently. One device failed because of mechanical damage at the time of implant and one failed due to premature power pack failure. This points out the difficulty in fabricating devices suitable for implantation with a high degree of reliability.

As can be seen, a modest amount of work has been accomplished in the measurement of in-vivo loads in implants. However, a successful long term measurement of in-vivo forces in the two most commonly implanted prostheses, namely hips and knees, has not been accomplished. Work has been underway for the past several years at our institution to develop prostheses which will permit the long term measurement of in-vivo loads. The primary purpose of this paper is to report on this work.

Specifically the data that are desired from the hip and knee implant telemetry projects are the actual in-vivo forces and therefore the loads that these devices are subjected to during the activities of daily living. The results of these investigations have two significant applications. First, these data will be particularly useful to the designers of these devices. Currently they are using best estimates based on available indirect and calculated data. That this sometimes is less than adequate is pointed out by the results of Brown et.al. (1982) where some of the loads born by the instrumented nail plate were beyond the capabilities some commercial implants being used. Given these in-vivo data

the designers would be able through proper choice of geometry and materials to design such implants better suited to their actual in-vivo environment.

The other area where these data will be of immense value is in the hands of clinicians relative to how they manage their total joint and implant patients post-operatively. Currently, the significant number of implant failures are probably causing clinicians to err on the side of caution in what they tell their patients they can and cannot do post- implantation. If truly accurate data were available it would be possible to much more precisely counsel these patients to avoid those specific activities which significantly stress the particular implant. This translates into the potential to increase the quality of life of the post-implant patient.

DESIGN CONSIDERATIONS IN INSTRUMENTED IMPLANTS

In the development of an instrumented device for implantation into the human body, there are two types of criteria that need to be considered. These are the patient related considerations and the technical or the engineering considerations.

Under patient-related considerations, any device developed for implantation in a patient must first and foremost be a fully functioning implant. That is the implant needs to be functionally comparable to the state-of-the-art commercial devices available. If any functional compromises are made in the design of the instrumented implant versus those routinely used from the commercial manufacturers, then the data acquired from this implant will be less than meaningful data and the patient may have less than an ideal implant. Another practical criterion that must be considered is the size of the patient population that is available for use with the developed device. Ideally the implant should fit a broad range of patients, since limiting the patient population to those at either end of the size spectrum will not give a good cross sectional representation of the in-vivo forces for the average implant being investigated.

Once the practical clinical considerations are addressed the device then must meet the technical requirement that it functions as a reliable, accurate data acquisition system. In so doing it must meet the primary criteria of being fully biocompatible for the expected in-dwelling life of the implant. In terms of some orthopaedic implants this can be measured in tens of years or even the lifetime of the recipient. Next, the amount of useful telemetric life must also be considered. The instrumentation should function long enough into the rehabilitative phase to get meaningful data concerning normal activities of daily living of the fully recovered implant patient. Unless sufficient instrumentation life exists the decision to be made is whether it is worthwhile to implant a unique device in the patient solely to determine the the best early post operative course of management of these patients.

In attempting to develop an instrumented implant which is both a representative functional design and a sensitive measurement device, the design engineer is now faced with another unique problem. That is, the design should be as strong as necessary to maximize its longevity as an actual clinical device. However, this typically runs counter to the instrumentation requirements of high sensitivity i.e. high deformability of the device under load. This conflicting set of requirements is perhaps one of the most difficult problems to deal with in instrumented implant development.

These issues are complicated by the fact that the groups dealing in implanted medical instrumentation have available to them a very limited armada of materials that the body will tolerate. Specifically in the metals these choices are limited to the chrome cobalt alloys, and a limited number of stainless steels and the pure and alloyed titanium. The lack of machinability of the chrome cobalt alloys generally makes them impractical for custom implant design. Therefore most implants today which are custom fabricated, with or without instrumentation, are done so using either the stainless steels or the titanium.

The final but definitely the most important criterion in any development program involving instrumented implants is acquiring data which will answer the questions being asked. Nachemson (1971) was most interested in the axial loads born by the Harrington rod during sitting and standing postures post operatively. His rods were so instrumented that these data were transmitted. In Rydell's (1966) work, in English and Kilvington's (1979) work and the work done by Brown et.al. (1982) the measured phenomena were those that were considered to be most critical to the particular device implanted. Clearly such considerations are necessary when such a project is undertaken. That is to say that it is fine to develop a device which is capable of functioning in a clinical environment and generating accurate data. However, if the data are of no relevance to either the clinician or the implant designer then the project is reduced to an academic exercise.

The way in which the above outlined criteria have been applied to specific projects namely the development and implantation of a series of hip nails, the development and to date singular implantation of an instrumented total hip and the ongoing development of an instrumented total condylar total knee will be described.

INSTRUMENTED HIP NAIL

In the design of the instrumented hip nail the first question asked was what is the primary data of interest regarding such a device. The answer to that question was provided by the fact that most hip nail failures occurred as a result of bending or failure at the nail plate junction. Therefore it was decided to instrument the device for bending in the two directions relative to the nail plate junction. On the basis of its relative contribution to failure loads for the nail plate, the axial loading on the nail was considered negligible. Therefore no attempt was made to measure it.

Having determined which data the device was targeted towards acquiring, the next step was to actually design the device itself. Given that the commercially available devices were showing a

high incidence of failure at the nail-plate junction, it was decided to fabricate a device which was stronger in this area than any commercially available unit. The actual device fabricated is shown diagrammatically in Figure 1. Note that the device is of a modified I-beam design, has sufficient materials removed from the nail so as to not interfere with the vascular supply of the head of the femur, has four holes provided for attaching the plate portion to the femoral shaft and has a cover which can be forced in place effecting a long term seal for the incorporated instrumentation. This device then met the previously noted criteria of providing a functional implant which was at least as strong and in this case better than those commercially available and did not unduly limit the patient population to which it could be applied. It was fabricated so that it met the long term biocompatability test, and through the use of internal switching the life of the telemetry was adequate to provide five months or more of data acquisition capability. This put us reasonably well into the return to normal function range for the patient population. In light of current knowledge it would have been more desirable to extend this life closer to a year. The material chosen for fabrication was 316L stainless steel which provided adequate strength, good machinability for custom fabrication, and adequate sensitivity in the nail plate junction. As noted earlier the usefulness of the data obtained was directly applicable to a revision in the design of the existing implants. Specifically, it was interesting to note that in some of the patients the magnitudes of the measured loads on occasion reached values which would have been critically high if standard fixation devices of minimal strength had been employed. Relative to post operative patient management it was noted that the ranges of loads encountered were fairly uniform between activities and within each activity which suggested a degree of self load limiting on the part of the patient. A secondary finding with this device was the uniformly high horizontal moments encountered relative to the value of the vertical moments.

TELEMETERIZED TOTAL HIP

In determining the data that would be appropriate to obtain from a telemeterized total hip joint, the basic assumption was that a total hip functions as a low friction ball-socket joint. Given this assumption, the data which are of interest are the 3-dimensional components of the normal contact force on the ball. The appropriate measurements to obtain are then the bending moments about the neck stem junction as well as the axial component of neck loading. Therefore a device was required that had a minimum of three data channels. The chosen design, shown in Figure 2, is one which involves a hollow neck section between the ball and the implant stem. In order to achieve the appropriate balance between strength and sensitivity of this section for instrumentation it was decided to fabricate this device from 6-4 ELI titanium. The actual configuration of the instrumented total hip is one that is reasonably current relative to commercially available devices and represents the clinical device primarily developed at the Hospital for Special Surgery. Again this device was subjected to laboratory evaluation to show not only its basic geometry but its long term loading capability comparable to implants currently on the market. The primary practical considerations of first and foremost being a functioning implant, secondly meeting or exceeding current commercial design criteria and third have a reasonable population range well met by this design.

Under the technical considerations the biocompatability criteria was met by isolation of the instrumentation entirely within the implant neck, effecting a metal-to-metal seal over the instrumentation compartment with a glass to metal feed thru for the antenna. Using new battery technology the life of the implant is projected to be between one and two years, well beyond the return to normal activities of daily living for the majority of patients. The data to be obtained for this device, as noted above, will be the continuous time profile of the force vector operating on the head of the device. Knowledge of this true in-vivo loading history will give design engineers the ability to simulate true in-vivo loading conditions on current and subsequent designs. It will also allow the clinician to identify with a high degree of certainty those activities which put undue stress on the implant. Conversely this will allow him to lift, hopefully, many of the current restrictions placed on most instrumented patients.

TELEMETERIZED TOTAL KNEE JOINT

The development of a telemeterized total knee joint is by far the most difficult and most ambitious of all current implant telemetry projects. The criterion that the telemeterized implant be first and foremost a long term functional device is a difficult criterion to meet while satisfying the requirement of telemetering out all the load data necessary. This is because all three components of the resultant force and the resultant moment about a point on the device must be measured if the true in-vivo loading history of the device is to be properly documented. Therefore the device must be a full six-degree-of freedom telemeterized load cell, and must meet all the previously stated requirements concerning implant strength, range of recipient sizes, and biocompatibility. Also because total knee joint patients may be somewhat longer in convalescing it needs to have a rather significant useful life, at least in excess of one year.

Again both the design and instrumentation engineer are faced with many trade offs in developing such a device. The choice of materials is still limited to the acceptable polyethylenes and above noted implant metals. A current prototype design which is presently being evaluated for implantation is shown in Figure 3. As can be seen from this figure the instrumentation is housed in a custom tibial component. The upper or articulating portion of the device does model the currently popular total condylar type of tibial component and will mate

with a commercial femoral component. Also by its very nature it models the metal backed version of this device. The stem however is slightly atypical although not unlike some of the newer devices which are appearing on the market. Therefore this device fundamentally meets all of the previously noted criteria. The major challenge in developing a device such as this is that of guaranteeing the long term biocompatability of such a multicomponented device.

SUMMARY

In summary, the development, implantation and data acquisition from clinically implanted devices holds out the promise of generating a whole new wealth of knowledge which will not only allow the development of new and better devices but will also put in the hands of the clinician the ability to better manage and optimized quality of life of the recipient of these devices. It truly represents the best of both worlds by the marriage of technology and clinical practice of medicine.

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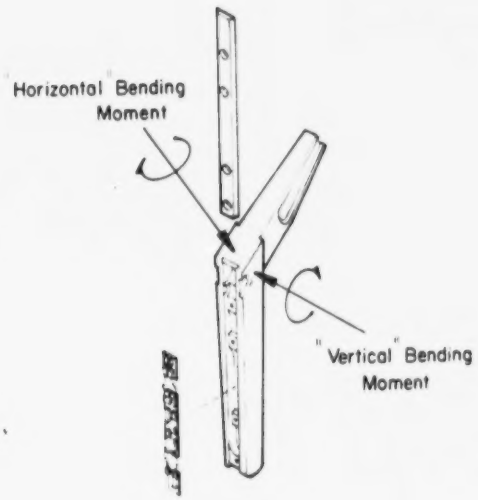

Figure 1

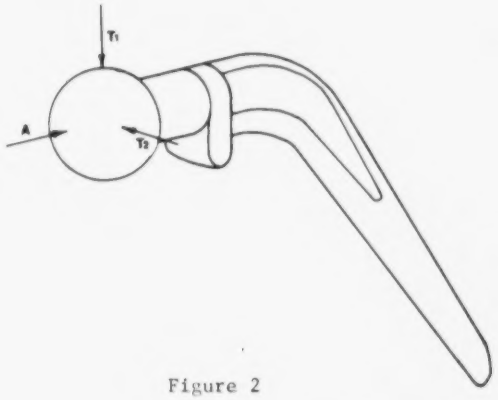

Figure 2

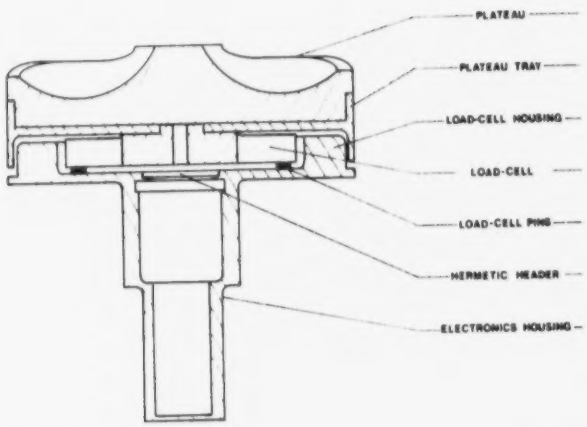

Figure 3

NEW MATERIALS FOR ORTHOPAEDIC IMPLANTS

R.M. Pilliar
Biomaterials Research, University of Toronto, Toronto Canada

ABSTRACT - Concerns over potential hazards related to trace ion release have limited new material innovations for implant application. Rather, better use of accepted materials by alternate processing methods or device design has resulted in improved implant performance. These will be discussed.

RÉSUMÉ - L'inquiétude causée par les dangers potentiels liés à la libération d'ions à l'état de traces a limité l'utilisation des nouveaux matériaux pour la fabrication des implants. Par contre, une meilleure utilisation des matériaux déjà reconnus, par le recours à de nouvelles méthodes de traitement ou de conception des dispositifs, a amélioré le rendement des implants. Ces questions seront discutées.

Introduction

The growing concern of potential hazardous long term effects of trace elements released from implants and their accumulation in body tissues, has had a profound influence on the introduction of new materials for surgical implants. This is particularly so for implants in orthopaedics where the larger implant sizes exaggerate this potentiality. The effect has been to limit studies on the use of new material compositions and, instead, there has been a greater emphasis on better use of presently accepted materials. Also, since elemental release from implants can occur by chemical (or electrochemical) degradation (corrosion) of the implant material, there has been increased interest in the use of more corrosion resistant, non-metallic materials. Aluminium oxide is a ceramic that has gained most attention in this regard with carbon and carbon composites (e.g. SiC/C) also being investigated widely.

The major identified problem related to the use of implants for joint replacements is implant loosening. To reduce the incidence of loosening, two general approaches have been studied during the past decade or so resulting in the use of i) modified bone cements and procedures for cement use and ii) porous structured implants intended for cementless fixation. Both these approaches have fostered their own unique set of problems that have and continue to occupy orthopaedic researchers.

Improvements in mechanical properties of the conventional implant materials have been achieved through refinements and innovations in implant fabrication methods. Additionally, better quality control of materials and final implant shapes have minimized the possibility of material-related implant failure so that, at present, the tissue-implant interface region and the mechanical and/or chemical (biochemical) instabilities that occur there are the problems that must be resolved for improved implant performance.

This review will present an outline of the modern implant materials used in orthopaedic surgery indicating the significance of processing to achieve properties. Also, there is a growing use of mixed material systems and/or composite-structured systems that can provide benefits. Examples of these will be discussed.

Metals - Most metallic implants today are fabricated from 316 L stainless steel, cobalt-based alloys or a titanium base alloy, Ti6Al4V. A Co-Ni alloy (MP35N) containing equal amounts of Co and Ni also is used widely and this should be considered as a separate alloy type although it has many similarities to the Co-based alloys. There have been extensive reviews of the processing and properties of these alloys (1). The major improvements in critical properties such as fatigue strength and corrosion resistance are related to i) elimination of impurities through the use of purer elemental additions and vacuum casting procedures, and ii) development of finer-grained structures through well-controlled thermomechanical processing (2,3), or the use of powder metallurgy techniques to achieve fully-dense parts by consolidation of very finely-structured atomized alloy powders (4). By minimizing chemical heterogeneities throughout and by maintaining fine grain structures, better mechanical and corrosion properties result.

There have been studies of minor compositional modifications with these alloys that have indicated mechanical property improvements. For both the Co-based alloys and stainless steel, slight increases in nitrogen content (up to 0.2 weight %) appear to increase static yield strengths (5,6) and corrosion-fatigue strengths (7). Our own studies on Co-based alloys indicate a benefit for the cast alloy (8).

To improve the forgability of the Co-Cr-Mo alloy, low C-level alloys with Cr levels also kept toward the low end of the specified compositional range (about 26.5 weight %) have been developed.

There have been a number of studies of hot isostatic pressing of cast Co-based alloys to eliminate internal casting-related voids. Studies have indicated that poor quality castings can be improved by this added processing step such that properties are comparable to good quality cast implants (9).

Possibly the most exciting area for future development of improved implant alloys is in the field of microalloying. Already the use of fine-structured atomized alloy powder consolidated to full density has resulted in higher strength Co and Ti-base alloys, (the Ti6Al4V parts so formed have been used in aerospace applications only to date). New developments to form even finer structured powders are in progress with great interest currently in the so-called amorphous or glassy metals. Superior corrosion and fatigue properties of these types of metal alloys will result in their future studies for implant applications.

In addition to studies on improvements through new processing of these well established implant alloys, limited studies have been reported on development of tantalum implants (10). The known good corrosion resistance of tantalum (due to formation of a stable, passive oxide layer) has been the major impetus for these studies. It is too early to say whether or not there is any true advantage to the use of tantalum as an alternative for orthopaedic implant fabrication.

Mixed alloy systems have been investigated because of the potential benefits of using different alloys in an implant system construction. Hence, the concept of using a better wear-resistant cast Co-based alloy for the bearing region of a femoral hip replacement component while using a higher fatigue strength alloy in the stem region is attractive. The consequences of alloy coupling on corrosion properties must however be considered. Griffin et al (11) have reported on the in vitro corrosion behaviour of a number of coupled alloys and reached the conclusion that coupling to 316L stainless steel could not be used with confidence while the other accepted implant alloys would probably behave suitably if coupled.

By combining particulate metallic matter with solid implants, a number of porous surfaced implants have been introduced recently for cementless implant fixation. Metal fibres (12) and powders (13) that are sintered to the solid implant surface both provided a means of forming dual-structured implants with porous surfaces into which tissue can grow and solid underlying substrates to provide the required mechanical strengths. Additionally such structures have been made by plasma spraying (14) and by pressure sintering of wire mesh ( ) to the substrate as well as by removal of sacrificial constituents through thermal treatments to form porous regions (15). All the resulting implants represent higher surface area implants (up to 10 x increase in surface area) and this has raised the question of potential long term consequences of metal ion release from these implants (16) that can become securely fixed by bone ingrowth thereby offering an otherwise attractive solution to the problem of implant loosening (17). The use of metals for load bearing applications such as joint replacement implants and fracture fixation plates and pins is due to the intrinsic fracture toughness and fatigue resistance of these materials. No other class of materials (ceramics, polymers, composites) presently can offer these features thereby providing mechanical reliability for implants.

Ceramics - Aluminium oxide (Al_2O_3) implants are being used for fabrication of orthopaedic implants that are loaded principally in compression. Excellent corrosion resistance and wear resistance makes Al_2O_3 an attractive material for fabrication of implants such as acetabular cups, femoral head components (either for surface replacements or for attachment to metallic femoral stems), tibial knee components and other parts that are loaded mainly in compression. Although possessing good compressive strengths, such ionic/covalent bonded materials have poor tensile and shear strengths and, hence should not be used for applications where large tension or shear loads must be resisted.

The mechanical properties of Al_2O_3 are strongly influenced by density and purity (18). Polycrystalline Al_2O_3 parts are fabricated by sintering alumina particles to nearly full density. A very small amount of residual porosity will persist in the highest quality parts and provided that this amount does not exceed about 0.5 volume % good quality parts will result. Careful batch to batch control is necessary, however, to ensure this high degree of density (19).

Enhanced particle to particle bonding occurs with Al_2O_3 because of less stable oxide impurities found on Al_2O_3 particle surfaces. Again, careful control of amount of these trace impurities is important to ensure stability of parts in vivo. Degradation of the material by grain boundary hydrolysis can occur (20) and such an event will lead to rapid breakdown of the ceramic through chemical and mechanical processes. Only the highest purity Al_2O_3 parts (99.8+) can be used for implant fabrication.

Carbon is an extremely biocompatible material that can be formed in very high purity. To provide the required mechanical strengths for load bearing orthopaedic applications, carbon fibre reinforced carbon, SiC/C composites and high strength isotropic carbon have been studied (21). The improvement of fracture resistance and fatigue resistance in particular, has been the major concern with these materials. Carbon fibres have been used for fabrication of polymer matrix composites as described below.

Polymers - The two most commonly used polymers in orthopaedics are UHMW polyethylene and PMMA (bone cement). Both suffer from inadequate mechanical properties that result in excessively high creep (or cold flow) for the UHMWPE and easy fatigue

fracture of the PMMA.

To enhance these properties studies of carbon fiber reinforcing have been reported for both materials (22,23). The reinforcement of polyethylene has been reported to provide better bearing surfaces for joint replacements although this result has been disputed (24). Similarly, although carbon reinforcement of bone cement does result in better fatigue strengths, other important cement characteristics (e.g. intrusion characteristics) suffer (25).

New processing methods and formulations of UHMWPE have been reported (26) and property-improvements appear possible. Clinical studies of these materials have not been reported yet. Similarly, use of low viscosity bone cements and various improved methods for cement preparation and insertion have been reported to provide better clinical results (27,28). The long term effectiveness of these techniques must be demonstrated through longer term clinical experiences.

Summary - Better implant materials and systems can only be positively identified through long term clinical follow-ups. The establishment of stronger device regulatory standards have limited clinical trials on new materials and implant designs. The complexity of the problem of ensuring long term success of surgical implants and the disastrous consequences of part failure supports such a conservative approach. Nevertheless, the need for improved materials and implant designs exists and, therefore, it is important that support of basic research in the field of biomaterials continues with government funding being the most likely source of support in view of the long periods necessary prior to widespread commercial application of innovations. Failure to provide this basic research support will result only in the failure to provide improved health care to the public at large.

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IMPLANT MATERIALS - CLINICAL CONSIDERATIONS

Hugh U. Cameron
University of Toronto, Toronto, Canada

ABSTRACT - The primary clinical consideration is that the implant should do no harm to the patient, either chemically, mechanically or in any other way, recognizing the present inherent fallability of our current best efforts.

RÉSUMÉ - L'essentiel, du point de vue clinique, est que l'implant ne nuise pas au patient, que ce soit chimiquement, mécaniquement ou de toute autre façon, tout en reconnaissant la faillibilité inhérente à nos meilleures réalisations actuelles.

The principal adage in medicine is primum non nocere - which is interpreted as, first, do no harm. Implant materials therefore must do no harm. "Harm" however is relative, not absolute. The only two certainties in life are death and taxes and taxes increase every year as regulations increase. Furthermore, we swim in a sea of carcinogens, drive large powerful automobiles at each other, sail on the sea risking drowing and fly in the air risking gravity and occasionally, defying the laws of thermodynamics when our planes run out of fuel. "Harm" therefore must be kept in perspective.

The only implant materials used in bulk are metals, plastics and ceramics. Ceramics, mainly fully dense aluminum oxide, are extremely hard and have very low friction when articulated with ceramic or with plastic. They are therefore useful as bearing surfaces. The particulate wear debris of ceramics is extremely benign and soluble products from ceramic hips do not appear to accumulate in the body. The problem with ceramics is that they are brittle and that voids and discontinuities do exist in multigrain systems. In Spite of all that can be done with quality control occasional catastrophic failure of such an implant is inevitable. In the Mittelmier ceramic hip for instance there has been one fracture in the last 4000 implantations.

What should be done? Should we ban ceramics as being inherently unreliable, which is a waste of a very good material. Or, should we switch to single grain aluminum oxice, which being gem quality has gem cost. This would be ideal of course but who could afford to pay for it?

The most commonly used plastic in implant surgery is RCH 1000 or ultra high molecular weight polyethylene. This plastic has been in use now for 25 years and there is no substitute even remotely obvious. It has reasonable wearing properties and is reasonably inert, but it seems unlikely that the first plastic to be used will not sooner or later be supplanted. At present clinical trials are under way with carbon fibre reinforced polyethylene. The wear properties of this composite are superior to that of pure ultra high molecular weight polyethylene but the material is much more sensitive to contact stresses. It remains to be seen whether or not the addition of carbon fibres will render the wear debris generated more tissue reactive.

Metals have been used for many years in orthopaedic surgery. They are mainly cobalt chrome alloys, titanium alloys and stainless steel. Both cobalt and chrome powder are toxic in tissue, as to some extent is nickle. Periodically an underemployed academic in search of a cause finds out this information which has been known to all practicing orthopaedic surgeons for at least 50 years and loudly trumpets messages of doom and disaster. It would be ideal if totally non toxic metals were available but they simply are not. It must also be borne in mind that there have been only two cases of tumors related to implants in the world's literature which now dates back 70 years with millions of implantations. The risk of tumor production therefore appears to be acceptably low.

In the original stainless steel Charnley hip replacement there was a 2% stem breakage rate. The orthopaedic companies have produced new super strength alloys which would seem to have solved this problem. Hospital administrators, alarmed at the high cost of implants, occasionally debate with surgeons vis-a-vis the acceptability of stainless steel. If there are 100,000 hips inserted a year in North America, this means that 2,000 stem fractures will occur per year. This does not seem acceptable to either the surgeon or the patient. It is not even acceptable to the orthopaedic companies who may be sued under the ridiculous concept of res ipsa loquitur every time an implant breaks.

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The problem with implant breakage is that the worse surgeon can always beat the best engineer, frequently helped along by an uncompliant and uncomprehending patient. There is not a bone plate in the world which cannot be broken if it is inserted inappropriately and/or loaded inappropriately by the patient.

All Governments wish to regulate implants in one form or another. At first sight this is a wise and worthy endeavour. In fact, a few minutes thought reveals the inappropriateness of these regulations.[2] Implant companies are in business to make a profit. They seldom make a profit on the first new item sold. Profit comes from repeat sales and therefore, implant companies are extremely careful in the product that they manufacture and sell. Similarly, if a surgeon has had a bad experience with one implant, not only will he stop using that implant but he will question the company's other implants. This is a time honoured and sensitive feedback system that Government is unlikely to help.

Indeed, it is difficult to see what the Government will regulate. "How long will one of these hip implants last?" asked one Government official. Obviously the implant will last longer than the patient and after creamation the only thing that will be left will be the implant. The question really is, how long will it function? This question, like so many good questions, is unanswerable. As surgeons see problems arise, implants are redesigned. The probable sales life of an implant is at present five years before it is superceded by a superior product. It is known that some of the original Charnley hips have functioned for more than 20 years but comparable figures are not available for any other implant. This data can only come from carefully controlled longitudinal studies which will take decades to perform.

Implants can be fixed to bone either chemically or mechanically. Experiments have been carried out for many years with bioglass which does bond chemically to bone. As yet no viable product is in sight and indeed most researchers with bioglass have abandoned it. The methods of mechanical fixation ultimately depend on surface area. Initially fixation may be achieved by a wedge or interference fit or by the use of screws, bolts, etc. Ultimately however, fixation really depends on surface area. Bone has a perferential stress window. If not loaded highly enough it may undergo stress relief osteoporosis as is seen in astronauts. If loaded too highly it resorbs to reduce the pressure. Currently most artificial joints are held in place with bone cement, a grouting agent. This cement is pressure injected into the bone and therefore vastly increases the effective surface area of the implant. Unfortunately, bone cement, which is polymethylmethacrylate, is not only relatively weak, it is relatively toxic also. A layer of granulation tissue appears at the cement bone interface and this layer slowly absorbs the underlying bone. If the patient lives long enough therefore the implant will inevitably loosen. Accepting this however, it should be pointed out that some cemented Charnley hip replacements have functioned for more than 20 years.

Recently attempts have been made to develop implants which can be held in place without bone cement. The concept of surface porosity into which bone will grow, has now proved itself in some situations such as knee replacement where it is loaded mainly on compression.[3] Great care has to be taken when using this material in deciding the optimum load transfer area to prevent severe stress relief osteoporosis. Other methods that function well, again in compressive load situations include ridged plastic pegs driven into undersized holes in the bone, and ceramic and metal screw cups in the acetabulum. That any method works in a shear load situation such as a hip stem remains to be seen. Design continues apace and sooner or later an acceptable solution will be reached.

The patients who require implants are frequently elderly with poor quality bone. Bone can vary in strength by an order of magnitude and some bone is almost too weak to realistically expect long term survival of any implant. Some bones also provide too small an anchoring area for satisfactory fixation. In the ankle for example, the talus is very small and geometrically complex. That is why conventional metal and plastic resurfacings of the ankle are never likely to give the superb results that can be achieved with hips and knees. Radical new concepts are required in joints such as this.

We speak of a joint as having "failed" when it loosens. It is technically more accurate to think of this as an artificial joint which has "decompensated". Failure is only failure if nothing else can be done. If the joint can be revised then it was not a failure. It was merely an event in a disease process. It behooves us as surgeons therefore to adopt the attitude that decompensation is inevitable and therefore before one operation is performed the next operation must be clearly visualized

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ENGINEERING DESIGN OF IMPLANT SYSTEMS

Greg McNeice
Professor of Civil Engineering
University of Waterloo, Waterloo, Ontario, Canada, N2L 3G1

ABSTRACT - Successful implant development requires the close cooperation of a multidisciplinary team. There are four essential phases of implant development during which the surgeon, the engineer and the manufacturer must interact. Good engineering design requires sound interactive analysis. Knowledge of analysis methods and a systematic approach to design can provide successful implants for surgical use. Careful record, assessment and communication of implant failure data is essential also to the future success of implanted devices.

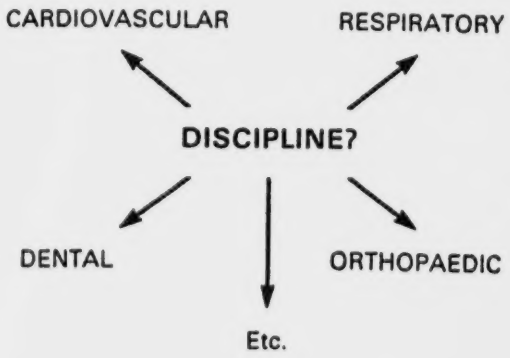
RÉSUMÉ - Les implantations fructueuses nécessitent les services d'une équipe polyvalente. Le concepteur doit posséder une connaissance des méthodes d'analyse et une approche systématique dans la conception et doit ensuite suivre les quatre phases de développement. Les données, les évaluations et les communications dans les faillites antérieures d'implantations sont essentielles afin d'assurer leur succès.

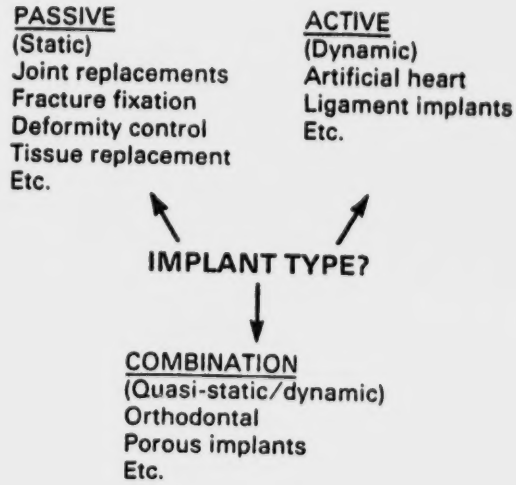
INTRODUCTION

Failure of any medical implant draws immediate attention and begs the question, "Why?". Failure need not mean fracture or fragmentation but simply inability to perform as expected. For example, in the case of the ball type heart valve, it may fail to provide sufficient seal during function or it may fracture due to fatigue of the cage. The type and mode of failure should be carefully assessed, recorded and communicated via scientific publication. There are many surgical implants and especially prostheses that are removed daily without any record made of the essential detail required to understand the "Why". The lack of failure data is not peculiar to any one discipline of which there are many. In orthopaedics the majority of implant failure is found in joint replacement prosthesis. In these cases, loosening of the implant is the most serious cause of failure. If this doesn't occur, then the implant usually fails by excessively deforming or even fracturing.

Within any discipline, the implant can be classified generally into one of three types. That is: Active, Passive or a Combination of these. Each type has unique requirements in its performance. Generally, an implant is required either to transmit large forces with corresponding small deformation or small forces, but with large displacement. Obviously, demands placed on the implant are varied and usually require considerable engineering input to both the analysis of its behaviour and the design of its replacement.

There is an ever-increasing demand for the professional engineer to join the medical group and help develop new materials, processes and implants. This requires the engineer to have fundamental knowledge of both analytical and experimental methods. Since design is essentially iterative analysis, the designer must be aware of the best methods to use to reduce the design time. Examples of mechanical analysis, either experimental or analytical, as they pertain to orthopaedic implant design, are outlined herein to illustrate the point.





MECHANICAL ANALYSIS METHODS FOR IMPLANT DESIGN

Various applications of solid body mechanics have been made to the analysis of implant devices in orthopaedics. The primary areas of research activity involve the human spine and the skeletal joints. The former demands stability and corrective devices while the latter requires replacement parts.

In spinal biomechanics, the latest implants and instrumentation involve "L" rods which allow the surgeon to tether the scoliotic spine and arrest progression of deformity. Classical methods of Euler buckling analysis are difficult to apply directly to the assessment of instability. However, approximate methods of structural analysis such as Newmark's method provide tractable and efficient analysis of the spine. Additional methods of "sidesway" analysis often used in the dynamics of multistoried buildings provide immediate insight into methods of improving L-rod instrumentation. Final assessment is made experimentally using a simulated mechanical ligamentous spine model. Results suggest that current L-rod stability for long thoracolumbar curves exceed that of the normal spine.

Spinal fusion techniques are assessed using classical column section analysis. Results suggest that anterior fusion provides ten times the resistance to flexion-extension than does a posterior fusion. Posterior fusion appears to resist lateral bending much more effectively. Experimental methods to assess fracture fixation devices are essential. Analytical and/or numerical methods are insensitive to the complexity of the fracture site.

In joint replacement research, the knee has captured the spotlight. Here, quite sophisticated three dimensional models using finite element descretization have been used. The principal goal has been to assess implant response to load and behaviour of the host site. Results indicate that metal backed tibial trays are essential to the success of these implants and help distribute the joint forces over larger areas and out into the cortical shell surrounding the tibial plateau. Classical analytical methods of analysis for the knee would require finite foundation deformation formulations capable of handling contact stress analysis between materials with widely different properties. Such methods would prove difficult to solve without introducing extreme simplifying assumptions and highly approximate boundary conditions. The finite element method is best suited to knee implant analysis. The author holds the view, however, that the problems of the knee have not been well defined to date. The parameters are many, far more than for the hip. We should first attempt to define implant failure, its initiation and progression. The modes of failure introduced in the literature can form the basis for discussion and future agreement for common clinical comparison. Mechanical methods of analysis were applied using data directly from existing literature in order to develop these "modes of failure" for the knee. Only after the problem is clearly defined can design criteria be meaningfully applied. Perhaps that is why there are over three hundred knee replacements on the market today.

Hip replacement research is still very much alive. Analysis methods for the femoral components of THA need not be as complex as the knee. Although a spatial stress analysis is applicable, the hip can be approximated well by simplified planar analysis. Finite element models in two and three dimensions have been many and varied. In most cases simplified composite beam theory would have been sufficient for practical purposes in implant design. Indeed, most of the femoral component stems in current use have been concocted, not designed on the basis of results from mechanical methods of analysis. There are a few that have been proportioned on the basis of implant analysis or in some limited fashion from experimental modelling. Most of the latest femoral components with the exception of one have been shaped to fill the canal in the medio-lateral direction. Analysis of these stems indicate that they will likely be safe against fatigue fracture when they loosen but they all cause excessive reduction in the bone stress fields. If it is assumed that these stresses should not be disturbed significantly, the implant should be designed to behave accordingly. The state of stress should be determined and attempts be made to restore it postoperatively. In long bones such as the femur, the cross sectional shape suggests that in addition to axial and bending type stresses, there are torsional shear stresses that should be assessed. These have not been included in finite element models since either a planar stress analysis was performed or symmetry was chosen to simplify the computation. Therefore, axial torque could not be modelled. The author has assessed the torsion stresses to be from 15% to 40% of the lateral principal stress at the critical section of the femur. Composite beam theory can be used directly to shape new stem cross sections that would restore normal principal and torsional stresses to 75% and 85% respectively. The importance of restoring the stress state when using an implant has not been established. Therein lies the greatest challenge in future methods of implant modelling. Only through well designed and carefully conducted animal research can we find and measure the input parameters for the implant mechanical model. The next generation of implants will take on an active rather than passive role and therefore must be designed accordingly. This will place a heavy tax on the mechanical methods of analysis. Time dependent material and geometrical changes will have to be modelled appropriately.

The marriage of mechanics and materials has pushed the frontiers of implantology. Now, the advent of tissue ingrowth sends the designer back to the drawing board. The task ahead is exciting, the prospects promising. These demands placed on the designer require him to approach the task in a logical manner. The systems approach to design that most professional engineers are taught will pave the way for successful implant design. Such design morphology combined with the following summary of the basic phases in implant development, should help

produce better implant devices in the future.

BASIC PHASES OF IMPLANT DEVELOPMENT

In the development of surgical implants there are four essential phases that should take place. These are as follows:

Phase I - Concepts and Comparisons

Assuming that there is a need for a new or modified implant, the first step involves unstructured brainstorming of conceptual ideas. These are created in concert with current knowledge gained from existing instrumentation and use. The fundamental material and mechanical requirements should be established during this phase. Preliminary analytical and experimental modelling are then conducted based on the concepts and component configuration that pass the selection criteria. Existing instrumentation or modifications of them play a major role in the completion of this phase. Basic performance criteria are selected here. The results of this phase should provide the fundamental envelopes of implant geometry and response vectors.

Phase II - Preliminary Design and Testing

The results of Phase I provide the performance criteria that guides the overall effort. Specific results provide for the establishment of design criteria which the device must satisfy. Selection of material, geometry and mechanical requirements are finalized during this phase. The design must satisfy all criteria including performance under mechanical loading and implantation. The product of this phase is an implant of preliminary design which has undergone sufficient performance testing and overall evaluation to allow Phase III to commence.

Phase III - Final Design and Testing

In this phase, the device or implant is fine tuned. The final selection of materials, implant sizes and component dimensions is made. Surgical tooling and assist devices are designed and tested. The mechanical tests usually involve both static and dynamic regimes which cover the anticipated range of loading and deformation. The performance criteria should be satisfied during this phase. The final design and support equipment can be forwarded to the manufacturing phase which follows.

Phase IV - Manufacturing and Distribution

Once the device is fully designed and tested it passes to this phase to allow production and distribution. In most cases, an existing manufacturer is chosen. This choice should be initiated during Phase III in order to allow close cooperation between parties prior to full-scale manufacturing.

Only after the above four phases are complete, is an implant ready for clinical trial. Throughout both preliminary and final design stages, an interactive and feedback loop of activities must go on. Although the phases outlined herein identify the major division in design morphology, there must be an appropriate interaction of design activities throughout.

CLOSURE

We must learn from our mistakes! Failure in implantology will increase if the physical and life scientists fail to monitor, assess, record and publish implant failures. The designer must be well trained in methods of analysis and understand the basic morphology of good design. The surgeon, the engineer and the manufacturer must work closely to provide the best surgical implants. Specialists in materials, methods of manufacture, mechanical analysis and clinical assessment are the major members of the implant team. Together they succeed, independently they fail.

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SPECIAL SESSION/SÉANCE SPÉCIALE 2

COMMUNICATION AIDS/

AIDES À LA COMMUNICATION

Chairperson/Présidente:

S. McNaughton
Blissymbolics Communication Institute
Toronto, Canada

AUGMENTATIVE COMMUNICATION: TRENDS AND PRIORITIES IN RESEARCH AND DELIVERY

Gregg C. Vanderheiden
Trace R&D Center, University of Wisconsin-Madison

ABSTRACT - Although augmentative communication started with the separate areas of language boards and writing/environmental control systems for vocal but physically handicapped individuals, the current focus of the field examines the entire spectrum of communication needs, including writing, conversation, and access to computer and information processing systems. Within these need areas, however, there are still the issues of rate, function, accessibility (portability and cost), and appropriate levels of technology.

EARLY WORK

The field of augmentative communication has its roots in two separate but concurrent areas. The first was the communication/language board work, carried on in a number of countries, but probably more clearly documented in the United States by McDonald, Sayer, Vicker, and others. From the work of efforts, largely clinically based came the fundamentals about communication and interaction development, and many of the basic techniques.

The second area of effort was based chiefly in Europe, and dealt with special writing and environmental control systems for vocal but physically handicapped individuals. The most widely known of these efforts were those of Maling, Jefcoate and colleagues at Possum, although the work in this area was by no means confined to this group nor to England. From this work came the early fundamentals for interfaces and automated selection algorithms. This work was first brought across the ocean by the Canadians, who were both importing and extending this work for some time before the United States became heavily involved.

In the United States, these two areas of effort came together with the passage of Public Law 94-142, which guaranteed all handicapped children an equal educational opportunity. Both teachers and speech and language pathologists were faced with a new population of individuals for whom they were responsible. Previously, such non-vocal and severely multiply handicapped individuals were not deemed candidates for the speech pathologist, and their educational opportunities were limited mainly to classrooms intended for more mentally retarded individuals. With the new legislation, individual plans tailored to their intellectual capabilities were required. As a consequence, new techniques and strategies were required to try to provide these individuals with effective mechanisms for communication. Speech pathologists, who had previously been told that communication boards were tabu, and had sometimes been threatened with firing if they applied them, suddenly found such approaches to be the only rational mechanism for providing effective communication to the more severely physically involved individuals. In an attempt to take some of the burden off the classroom teacher and aides, more independent means for communication were also sought. Techniques developed previously purely as writing systems were brought into application in order to provide more independent mechanisms for conversation.

FROM WRITING TO CONVERSATION TO BOTH

An interesting trend occurred during this process, particularly with regard to automated aids. Initial work was focused on writing systems, largely for individuals who did not have a speech impairment. Later applications, especially with regard to portable systems, tended to focus more on the conversational aspects. This is perhaps partly because the speech pathology field played such an important role in this phase, and partly because conversation comes before writing in most of our own developmental histories. Early aids had only print-outs for use in conversation, and therefore provided some measure of written communication as a sort of side-effect. With advances in technology and voice synthesis, aids began to appear which focused only on the vocal or conversational aspects of communication. For a while, conversation-only aids were sought, and the importance of writing for many of these individuals began to be overlooked.

More recently, however, the focus has broadened, and the total communication needs of these individuals are being considered. We now recognize that there is a full spectrum of communication needs, including

- quick phrases and interjections
- messages
- conversation
- writing
- access to electronic information processing systems

The field therefore now addresses the full spectrum of communication needs for these individuals, some of whom have only minimal speech difficulties, or none at all. However, it also includes individuals who are very young and/or severely retarded, for whom an effective mechanism for conversation is the primary or sometimes only focus.

CURRENT ISSUES AND TRENDS

Although we now recognize a diversity of communication needs, the basic priorities within these needs have not really changed much. These still are:

- Rate
- Function
- Accessibility: Portability
- Accessibility: Cost
- Appropriate Level of Technology

Rate

The rate problem is a more severe problem with conversation than with writing (although, as discussed below, it may get worse for writing). The normal rate for conversation is somewhere around 180 words per minute. A normal handwriting rate is in the range of 30-35 words per minute. Thus, one can see that it is 5-6 times easier to provide an individual with an effective and rate-competitive mechanism for writing than for conversation.

The important thing is that a faster rate is not just "nice". Unless a certain sufficient rate is achievable, it may be impossible to carry on a conversation as we know or define the word.

With advancing technology, we've been able to implement more involved selection schemes, increasing the potential rates for communication. In fact, some old schemes that were unworkable or impractical without technology have now become practical. Use of a short-hand to speed output from a physically handicapped individual, for example, was a nice idea, but who could read the output? With acceleration techniques such as Speedkey, however, gains of up to 300% (average -- higher for phrases and sentences) of normal typing can be easily achieved using a portable computer to translate the short-hand as it's typed into full text for display or print-out (Vanderheiden, in preparation).

Semantic-based sentence encoding techniques such as Minspeak (Baker, 1982) allow common, often-used sentences to be rapidly accessed.

Techniques such as those developed at Michigan State University (Eulenberg et al., 1977) and in Sweden (Carlson et al., 1981) allow individuals to output the basic sentence structure and have the computer clean up the tenses.

These techniques and others like them provide hope that writing speeds can be brought up to rates near the normal writing rate. If the individual has 10 fingers and can type at the rate of 60 wpm, then these techniques could approach the 150-180 wpm range of normal speech. For those individuals typing 1 key per second (about 6-10 wpm), it is now reasonable to look toward to 20-35 wpm, or essentially the normal handwriting rate. For those individuals typing 1 wpm, however, we're still going to be in the range of only 3-6 wpm, except for those sentences which are stereotypic or predictable enough that they can be pre-stored. In addition, even with the fastest and most powerful techniques, conversational rates are still way out of reach.

Function

While all aids provide some function, the issues of "sufficiency" and "full communication needs" are still problems. For example, it is true and accurate to say that providing a child who had no means to communicate with the ability to communicate at 1 word per minute is a fantastic advance for the individual. It is, in fact, an infinite gain in communication rate. However, compared to the 180 wpm at which everyone else converses, it is far from adequate. Even an individual who is able to communicate at 10-20 wpm would not be invited to present at this conference. Similarly, his or her opportunities for conversation, and contributions within a conversation, would be far more limited than we would deem acceptable for ourselves. Thus, in order to look at a functional an aid is, we must not look at whether the aid merely "is useful" or "helps," but rather look at what the individual will actually be able to do with the aid, or what we would be able to do if limited to the maximum communication abilities providable by the aid in question.

Although rate is probably the major problem, especially with the more advanced individuals, it is by no means the only problem in this area. With some phrase- and sentence-based techniques, high speed communication is possible, but the range of topics, and what can be said about them, is extremely limited. A normal 5-year-old has a 2,500 word vocabulary, and can express millions of different sentences and ideas. Communication systems with 100 words or 3,000 sentences only begin to address this communication need.

For pre-spelling individuals, the problem is even worse. A spelling individual can always get the idea across if he or she can take the time to spell it out. For pre-spelling individuals, it is next to impossible to provide a mechanism that will allow them to access the tremendous vocabulary needed to say all the things they will want to say in the words they will want to use or are familiar with.

It is also important as we look at the function of a communication aid to realize that there is a full range of quite different conversation and communication needs which should be considered. These include

- Quick or emergency messages -- "I need to go to the bathroom," "I'm thirsty," "I'm hungry," etc.

- Phatic phrases, which provide feedback and help check the channel of communication, such as "I see what you mean," and "I'll go along with that." These are non-specific, often used, but need to be uttered essentially spontaneously to be effective (Baker, 1982).

- Stereotypic messages -- words or phrases which come up repeatedly or predictably for an individual, and which he/she can pre-program into the aid and call up with a few keystrokes as needed.

- Novel conversations -- The bulk of communication, which can be neither predicted nor prestored, and which must be assembled word by word, and often letter by letter. Work by Beukelman et al. (1981) suggests that this might constitute most of our daily conversations.

- Writing -- This includes portable writing and note-taking as well as workstation writing. It also includes both the repetitive types of writing and novel/creative writing.

- Computer access -- This includes access to computer-aided instruction systems, telephone communication systems, and the information and data-processing systems being integrated into our society.

The recent trend has been toward more multi-functional aids; toward aids which can address both conversational and writing needs, as well as the prospect of access to computers (via keyboard emulators) as these enter the individual's life. There are still some single-function writing aids for individuals who have speech. There are also some conversation-only (voice only) aids which have good application with some of the more severely retarded population. There is a real danger, however, in providing such aids for individuals who have any opportunity for learning to recognize words, etc. For such individuals, it is important to look at the full spectrum of needs in order to avoid a situation where the purchase of an aid to meet one need blocks the ability to secure additional functions needed to meet the rest of the individual's needs, either at the present time or in the near future.

In addition to aids which address both conversation and writing, we are also beginning to see consideration being given to the development of multi-modal aids. These multi-modal aids would provide fast access to pre-stored sentences in order to handle the predictable and phatic types of communication needs, but still allow straightforward use of word-based acceleration techniques to handle the more novel and unpredictable communication needs that form the bulk of the individual's communication.

The problem of providing young pre-spelling children with effective mechanisms for communicating on broad ranges of topics is still very severe. The Bliss symbols have been one very effective way of approach this problem. Other symbol systems have also picked up on and incorporated the idea of using more concept-based rather than concrete-based vocabulary items to allow children to reference a much broader range of topics in their communication repertoire. With advances in voice synthesis technology and our understanding of its use, it will also be interesting to see whether very young children can be taught to phonemically or phonetically construct words which they hear in their environment, thus providing them with a "phonetic alphabet" which they can use to construct words. This would allow these individuals full communication access for the first time.

Access: Portability

Portability, or "accessibility in different environments", can be thought of as an aspect of Function. If one addresses the Function question above by looking at what an individual can and needs to do, and the environments in which he/she must do it, then portability becomes an obvious aspect of Function. However, it is all too often overlooked, and is therefore included here as a separate consideration. For example, it still common to find individuals who have developed a conversation aid for a totally non-vocal individual based on an Apple or other computer. Having a conversation aid which plugs into the wall strikes me as being about as useful as a hearing aid which plugs into the wall, or an artificial leg on an extension cord. It is not that such aids do not have any function; they might, for instance, meet the needs of a totally bed-ridden or room-bound individual. However, for any other individual, their usefulness would be extremely limited.

Portability does seem to be automatically coming with advancing technologies. A large application for the new portable computers is word and text processing. As a result, these portable computers lend themselves to modification via reprogramming to form compact portable communication systems. The biggest problem, however, comes from interfacing. Many of the portable computers do not provide for a wide variety of special interfacing techniques. Hopefully this is a short-term problem, and switch inputs will be included in future versions. For many individuals requiring expanded or special keyboards, head-pointing sensor panels, etc., special interfaces, often several times the size of the portable computers, will still needed. Fortunately, those individuals who are ambulatory and for whom portability has been the biggest problem can more often than not make use of the standard keyboards on the computers if keyguards and similar modifications are provided.

Access: Price

This has always been a problem, but it is more of a problem now than in the recent past. This is due both to a restriction in funds and escalating costs. The higher costs, however, are usually not due to the technology, but to the other aspects, such as marketing, which are characteristic of the field. These include

- training costs
- demonstration costs
- low volume
- obsolescence
  - due to better designs
  - due to better technologies

In fact, the majority of the costs lie in these areas, and not in the technologies themselves. Any meaningful effort in this area therefore has to be directed toward these areas, since most of the other aspects are based upon man-power, and those costs are continually rising.

The best hopes for containment or reduction of costs in rehabilitation aids are:

- technological advances, which result in both lower costs and more flexibility. These in turn can result in broader application, less need to secure additional aids, and longer useful life for the aids with a given individual.

- better manuals; although expensive to develop, better manuals can greatly reduce the amount of training time required, the amount of support required from the factory after purchase of an aid, and also a better understanding of the aids at the clinical level, reducing the need for demonstrations or repeated demonstrations. Better manuals can also increase the number of placements which are successful, increasing clinician and funding agency confidence in the aids and again increasing their application.

- better clinical training; both in the application of aids and in what's available. More information on application can reduce the manufacturer's costs by reducing both the support needed to clinicians and the training and follow-up with individual clients. More information on what's available can reduce misapplication and increase the application of newer aids by having a broader clinical population who are aware of them.

- more clinical support of manufacturers; through pooling of demonstrations and other strategies by clinicians to reduce the cost of disseminating information and supporting clinical facilities, clinicians can lower the costs to manufacturers and thus lower the cost of the aids. If manufacturers are viewed as part of the team rather than profiteers who should be tapped whenever possible, overall costs may be reduced. After all, if manufacturers are making a profit off the handicapped, so are all of us clinicians.

- more application; as aids receive broader application, the costs for information, demonstration, training, development of new aids, etc., all are spread out across a larger base, and the cost for individual aids goes down. More application will come from two sources. One is better coverage of the handicapped population, as the aids become genuinely useful, and more people become familiar with them. In addition, as aids become more flexible, specific aids will also be appropriate to a larger portion of the handicapped population by being able to address the needs of a broader range of abilities and disabilities.

Appropriate Level of Technology

We also need to better understand how to make best use of all of the levels of technology in the communication process. A common misconception is that a technologically advanced aid replaces a more fundamental aid. In fact, most successful physically handicapped communicators have both automated and fundamental communication techniques which they mix and intermix to capitalize on the advantages of each.

We used to believe that the higher technologies were for the brighter users, since it took more intelligence to figure out how to control the aids. In fact, advancing technology usually leads toward aids with simpler functioning. (For example, the more advanced television sets have fewer and fewer controls to them, turning over adjustments and tuning to automatic circuits.) We are just now entering the age where aids can be made powerful enough to begin to have application with some of the more retarded individuals in our populations.

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TEACHING THE PROFESSIONAL HOW TO ASSIST THE INDIVIDUAL WITH A SEVERE DISORDER OF COMMUNICATION

R. Fawcus
The City University, London EC1, England

ABSTRACT - This paper examines the major problems involved in training professionals in the assessment and prescription of aids and the overall management of the individual with a severe communication handicap.

RÉSUMÉ - Lors de cette présentation seront examinés les problèmes, dans la formation des professionnels, qui dominent l'évaluation et l'ordonnance des aides électroniques, et le soin complet de l'individu profondément handicapé dans ses capacités de communication.

The administration of services for those with severe communication handicaps involves a major educational process within national boundaries and importantly from one country to another. It is essential to regard this activity as a two way process, for no individual state has so far achieved a comprehensive program of research, development, assessment and service delivery.

One of the principal problems posed for those who attempt to provide education and training in the field of augmentative communication is the marked resistance which is typically encountered from a high proportion of those involved.

This paper explores the reasons for rejection of communication aids by both professionals and consumers, the possibilities for encouraging acceptance where appropriate and the individual requirements of the wide range of personnel involved.

Not everyone, it must be said, lacks enthusiasm for augmentative aids. Some therapists, engineers, consumers and their relatives have extremely positive attitudes towards communicative devices. The reasons for this sharp divergence of opinion are complex and little evidence exists so far to help clarify the situation.

In the nineteen fifties it was confidently anticipated that there would be a universal acceptance of high technology designed to alleviate the problems of the handicapped. When these devices were in their conceptual stage it was easier to enthuse about their amazing potential.

The problematic development of the laryngeal prosthesis may serve as an example. It was probably the earliest type of communication aid, designed and produced in the latter part of the nineteenth century at the same time as the operation was performed which made it necessary. Unlike so many succeeding types of aid the pneumatic pseudo-larynx provided a remarkably good substitute for the capacity which had been lost. It was assailed, however, by severe competition from an unexpected source.[1] Laryngectomised patients attending follow up clinics began to exhibit oesophageal voice which served as a rudimentary but effective means of communication. Oesophageal voice did not sound as 'natural' as pneumatic devices but was a greater success fro both cosmetic and efficiency stand points.

It took almost a century before any serious alternative device was developed. The vast majority of electric pseudo-larynges offered relatively crude technology with even cruder acoustic output. Few, with notable exceptions, have ever been popular with patients, families, therapists and co-professionals.

The problem besetting the development of an effective, acceptable laryngeal device epitomise the setbacks encountered in so many aids currently under development and emphasise the difficulties incurred in professional training.

To expose students to a mere catalogue of existing equipment with appropriate demonstrations tends to trivialise the problem in introducing the aid to the individual who may require it. Assessment of the patients' needs is a complex and difficult task but management of the situation following assessment is even more complicated than the assessment.

The psychological, linguistic and bio-engineering factors involved in the task

TECHNOLOGY PERSPECTIVE

G. Fagerberg
Handikappinstitutet, Bromma, Sweden

TEXT OF PRESENTATION NOT AVAILABLE

TEXTE DE LA PRÉSENTATION NON DISPONIBLE

TECHNOLOGY AND SERVICE FROM A NATIONAL PERSPECTIVE

A. Sylvestre
C.R.F., Lorient, France

TEXT OF PRESENTATION NOT AVAILABLE

TEXTE DE LA PRÉSENTATION NON DISPONIBLE

PROCEEDINGS OF THE 2ND INTERNATIONAL CONFERENCE ON REHABILITATION ENGINEERING OTTAWA
COMPTE RENDU DE LA 2e CONFÉRENCE INTERNATIONALE SUR LA RÉÉDUCATION FONCTIONNELLE 1984

CONSUMER PERSPECTIVE - CONSUMER INITIATIVE: WHERE DO YOU GO? WHO DO YOU ASK?

Nola Millen, (User), Windsor, Ontario
Pat Cashdollar (Parent), Dayton, Ohio

ABSTRACT - Non-speaking persons want to become communicatively effective individuals. This requires aggressive, active intervention by the professionals who work with them. Two consumers who have taken the initiative will share information on their effort and what is available from their perspective.

RÉSUMÉ - Les personnes non parlantes veulent devenir des personnes efficaces du point de vue de la communication. Cela nécessite une intervention active et agressive de la part des spécialistes qui travaillent avec ces personnes. Deux consommateurs qui ont pris l'initiative dans ce domaine nous feront part des efforts qu'ils ont faits et de ce qui leur est disponible.

Non-speaking persons want to become communicatively effective individuals. This requires aggressive, active intervention by the professionals who work with them. Too often the school speech therapist hasn't had to deal with a child who cannot talk. Too often the early childhood program at the social service agency is served by part-time consultants for language development programs. Too often medical professionals see too few babies born with developmental disabilities. Too often adults who sustain traumas that result in the loss of speech are left without the active intervention and support required to put their lives back together as far as possible. This need not be the situation today.

Information is available to share within the disciplines that impact on the life of the person who is in need of an alternative or augmentative communication system. Technology is available to the professional and to the consumer who needs an alternative or augmentative communication system. Materials have been developed that will enable a psychologist or a neurologist to assess the abilities of a person who needs an alternative or augmentative communication system. Professional support is available to the speech pathologist, the occupational therapist, the classroom teacher who works with an individual who needs an alternative or augmentative communication system. Where do you go? Who do you ask?

As parents of a child who was born with cerebral palsy with motoric involvement so complex, so complete, there was no hope for functional speech, there was no single person who could help. The skill that is required to address the needs of the individual so involved is found in a team of professionals — a group of people with training to address the gross and fine motor needs, the positioning and mobility needs, the psychological and social needs, the communication and educational needs, the medical and leisure needs.

This team of persons needs to be able to communicate with one another and therein lies one area that is only beginning to be addressed by those who have had success in intervening on behalf of the severely and multiply-handicapped individual. Our family has always had a large team of persons we relied on to manage the many concerns we faced after our daughter was born. The people on this team interacted with our family on an individual basis and the family was required to do most, if not all, of the case management without communication between the team members themselves. There is no new story here. We have seen improvement in the area of teaming. We have seen the team evolve from a multi-disciplinary group to an inter-disciplinary group through trans-disciplinary approaches. At least in the literature and in theory. In practice, there is room for improvement.

From birth or from onset of the condition, there needs to be a greater effort from the medical profession to honestly advise the family as far as possible on the implications of the case and the alternatives available to the family. Active family involvement is highly recommended. It is the single most effective treatment, if you will, for the benefit of the individual who is unable to speak/communicate.

Because the professionals were 'not there' for us when we needed information, we have had to search out the people with the answers and the programs that were working to properly assess our child. In this respect, perhaps, we do not represent the majority of consumers. It is difficult to imagine parents unwilling to cooperate with recommendations made to introduce a child to an alternative communication system, yet, we are told there are such situations. We have been involved in a parent-to-parent support group for over thirteen years and we feel this is an issue to be debated. The parents are the only constant members of the team for the child/individual who is non-verbal. As such, the family needs to be involved from the beginning in the

decision-making process if they are to actively advocate on their own behalf. Properly prepared and supported in their role, parents will cooperate and actively assist in the management of their child's program in most instances.

Having to identify resource people and services outside our community, we were able to obtain the information and equipment we needed when our daughter was younger. The availability of equipment and devices isn't as much an issue as convincing reluctant professionals who weren't involved in the selection process to accept the recommendations of others who have had more opportunity or experience in the field.

Today, there is not one professional on our daugher's team who is convinced this sixteen year old young woman could benefit from being able to express herself with a voice output communication aid. In that respect, we need to take a serious look at our situation and at the people we have to depend on to assist us in future endeavors. We feel strongly that there needs to be more information sharing within and across disciplines.

Where do you go? Go to I.S.A.A.C. The International Society for Augmentative and Alternative Communication was formed in May of 1983. There will be an International Conference at the Massachusetts Institute of Technology (M.I.T.) in the Boston area October eighteenth through October twentieth. The purpose of I.S.A.A.C. is to advance the transdisciplinary field of augmentative and alternative communication techniques and aids. I.S.A.A.C. will facilitate an exchange of information and focus attention upon the work being done to help people with communication difficulties throughout the world. There are brochures available that will introduce other services and functions of I.S.A.A.C. to you. As a parent and consumer advocate, I would ask you to investigate the organization and particularly recommend the Advocacy Committee activities. The areas of public awareness and public education, linkage with agencies and programs within the international community, information and referral services for consumers, parents and professionals throughout the international community and technical assistance for local or regional support groups are planned to provide a 'place to go'.

Who do you ask...? The leadership of I.S.A.A.C. is present at this Conference, participating in this program today. The participants on this panel presentation and the contacts listed in the I.S.A.A.C. brochures distributed here today are people who are willing to act as support for your effort on behalf of any individual who is in need of an augmentative or alternative communication system. They/We can provide information from interactive behaviors that can occur between two individuals through complex cooperative arrangements at an international level. There is one more thing needs to be considered when considering who to ask — beyond the person who is able to invent or develop systems — beyond the person who can provide the assessment and design the program -- beyond the person who can enable the funding of the equipment — all of these things are useless without the time taken to allow the individual who is unable to speak the opportunity and dignity accorded others — the freedom of expression.

Non-speaking persons want to become communicatively effective individuals. This requires aggressive, active intervention by the professionals who work with them. Professionals need to realize that we as non-communicative disabled people ought to have our questions answered by them.

As a youngster, and even in my early teens, I found there was a kind of fear in the professionals when communicating with a consumer. A lot of professionals allow parents or teachers to be the mediators which is wrong. An adolescent is not going to gain independence when he or she can't communicate with those professionals who are advising a major decision. It was only when I took the initiative and started refusing to leave the professionals and their office before they gave me answers, and refusing to let them make any comment in front of me that they started talking directly to me.

After I began demanding to know answers, the professionals started listening to me and soon found that there were numerous areas overlapping in my treatment. Professionals need to take the time with everyone despite the worst communication problem and work with the disabled individual instead of just those around the person.

These remarks are taken from a presentation by Michael Williams, Santa Rosa, CA They need to be said again.

"As a communication aid user I spend much of my time in my community talking to people. This is public education. Such education is necessary before the new speech technology can spread beyond a few individual users.

"Potential communication aid users must become aware of the political process in their area of residence. They must participate in this process as much as possible. They must learn who represents them in their governmental structure. Above all, potential communication aid users must vote.

"Parents of speech impaired children must band together in their local areas and develop action plans to get this speech technology into the hands of the children who need it.

"Speech therapists must lose their fear of technology. I have met many therapists who express great amazement when I use my voice-output communication device. The two most frequent questions I get asked are, 'How does that work', and 'How do you remember all those codes?' The answer to these questions should be a part of a speech therapists continuing professional education.

"...consider implementing a project that would provide a state-of-the-art communication device to at least one communication aid user in each member country. These users would be our ambassadors. They would offer hope to other potential communication aid users. Such a project would provide an immediate sharp focus for this international organization in addition to providing some people with the technology they need to communicate.

"A tall order? Sure it is. An impossible task? Perhaps. But can't we at least consider the possibliity?"

GRAPHIC SYSTEMS: AN OVERVIEW

Lyle L. Lloyd, PhD, Purdue University, West Lafayette, IN 47907, U.S.A.
Chris Kiernan, PhD, University of Manchester, Manchester M13 9PL, U.K.

ABSTRACT - A brief overview of the wide variety of graphic symbols/systems available. Rebuses, Sigsymbols, Blissymbols, and symbol accentuation - presented to illustrate the basic dimensions of such symbols/systems. Issues are raised about their use with handicapped individuals.

RÉSUMÉ - Un résumé court est présenté de la grande variété de systèmes et de symboles graphiques. Les systèmes comme Rebus, Sigsymbols, Blissymbols et "symbol accentuation" (l'accentuation des symboles) sont présentés afin d'illustrer les dimensions fondamentales de tels symboles et systèmes. Des questions relatives à leur emploi avec les handicappés sont discutées.

Graphic symbols and/or symbol systems employ visual symbols which may be available in permanent form (e.g. on paper or cards) or semi-permanent (e.g. on a television screen). Graphic symbols/systems* have also been defined as aided since they require some type of external assistance or an aid such as paper, pencils, pictures, charts, boards and in some cases electronic devices (Blau, 1983; Fristoe & Lloyd, 1979; Karlan & Lloyd, in prep: Lloyd, 1980a, 1980b, 1984; Lloyd & Karlan, 1982, 1984). They are usually visual-spatial rather than visual-temporal and,because of their usually enduring nature, are sometimes referred to as static rather than dynamic. (Dynamic or unaided systems, include gestures, manual signs and speech). Graphic symbols/systems which are more commonly used along with systems which have particular features of interest are as follows: pictures (photographs and drawings including basic rebuses), Picsyms, Sigsymbols, Pictogram Ideogram Communication (PIC), Blissymbols, expanded rebuses, Mosman Sounds and Symbols, other logographs, Lana Lexigrams, Premack-type Symbols, traditional orthography (TO) including printed words and writing, and symbol accentuation or modification.

The symbols/systems are listed in terms of a general hierarchy from the use of actual photographs or colour pictures to traditional orthography (TO). This hierarchy confounds dimensions such as abstraction, arbitrariness, cognitive requisites and approximation to the natural spoken language (Lloyd & Karlan, 1982, 1984). Considerable information on the wide variety of symbols/systems is available (e.g. Clark & Woodcock, 1976; Karlan & Lloyd, in prep; Kiernan, Reid & Jones, 1982; Lloyd & Bloomberg 1984; Musselwhite & St Louis, 1982). Some of the major dimensions can be illustrated by brief characterisation of selected systems.

Rebus is listed above twice because there are two types of rebuses that may be used as a nonspeech communication system. The term 'rebus' comes from the Latin for 'thing' and by definition means a representation of words or syllables (1) by picture (or object) symbols or (2) by symbols whose names resemble the intended words or syllables in sound.

At one level rebuses are pictographs, which we refer to as basic rebus. These symbols are pictures of objects, e.g. tree or ball. Others are more abstract, for instance the symbol for 'run' is a picture of a 'stick-person' in a running posture. Basic rebus also includes symbols which represent prepositions. Here a non-figural entity is used, for instance a black circle, which is placed in various relations to box-like figures in order to represent 'on', 'in', 'under', etc. Direction of movements or movements of objects can be indicated with arrows. Basic rebuses of this type are the fundamental elements of the Standard Rebus Glossary and the Peabody or AGS Rebus Reading Series developed by Woodcock and his colleagues as a system to aid in learning to read (Clark, Davis & Woodcock, 1974; Clark & Woodcock, 1976; Woodcock, 1965). This is the most frequently used rebus system for teaching reading and with minor variation has been used as the basis for graphic communication symbols (e.g. Clark & Woodcock, 1976; Van Oosterum & Devereux, 1982). As communication symbols the basic rebus may be considered essentially the same as other pictographic systems such as the Picture Communication System (Johnson, 1981) or the Oakland Picture Dictionary (Kursten & Bernstein, 1981).

At a higher cognitive and linguistic level are more complex and/or arbitrary levels of symbols we refer to as the expanded rebus to make a clear distinction between the use of pictographs and very basic ideographs at the basic rebus level and the more complex ideographs and arbitrary symbols used in the expanded rebus. The expanded rebus includes symbols representing words or syllables in sound and the combination of rebuses with letters representing sounds. The symbol for the verb 'to be' may be represented by a picture of a 'bee', 'cannot' by a picture of a 'can' next to a 'knot'. This use of rebus arises from the

* Symbols/systems is used when the ambiguity of "symbols and/or symbol systems" is intended.

original purpose of the system, as an aid to reading. The purpose is also illustrated by the use of symbols involving letters, for example the symbol for 'cold', a picture of a bald man with a beard with the letter 'c' to the left of the picture. The AGS Standard Rebus Glossary contains a large number of words represented by expanded rebuses that may be of value in teaching reading, but are of limited value for communicative use by cognitively limited individuals.

Sigsymbols (Cregan, 1982) were developed for use with severely mentally handicapped children as an aid for teaching language and initial reading skills. The symbols are again of various types, some pictographic, some involving stick people, some an abstract 'thing' used for instance in the symbol for 'give' along with directional arrows. Sigsymbols also use a different type of symbol, representing the form of manual signs in British Sign Language. These may be realised by either picturing the sign, with a head and hand and directional arrows reflecting movement, or by simply showing the signs. The inclusion of these symbols reflects the use of manual signing with mentally handicapped children as an aid to communication and language.

Blissymbols (Bliss, 1965) were developed initially as a concept-based system for international communication. However, the system has been more commonly used as a communication system for physically handicapped individuals (Hehner, 1980; Kiernan, Reid & Jones, 1982; McDonald, 1980; Silverman, McNaughton & Kates, 1978; Vanderheiden & Grilley, 1976). The system is constructed from 100 basic elements, lines and curves, each of which has ascribed meaning. An inverted V represents action, a triangle base-line down, creation, an upright line with a short base-line, a person. A combination of the action and person symbols signifies a person of action, a male, combining the creation and person symbols represents a female. Adding another inverted V, the symbol for protection, at the top of the symbol, gives symbols for father and mother, protecting males and females. The symbols also become stick figures of a man, in trousers, and a woman, in a skirt. Blissymbolics resembles other systems in having a combination of pictographic, ideographic and purely abstract symbols. As we have noted, the function of the symbols is governed by rules, although modifications are clearly necessary in forming some symbols (e.g. in the form of the person symbol when deriving the male and female symbols). In addition to the logic, the strength of the system rests on the very large number of symbols which are available and on the existence of an organisation which co-ordinates the generation and dissemination of new symbols and information about use.

Symbol Accentuation (Clark & Woodcock, 1976; Miller 1968) typically refers to a principle whereby words written in TO are complemented or modified by adding elements which reflect their meaning. So the word 'look' is complemented by making the O's into a pair of eyes (adding pupils and eyelashes). Symbol accentuation was again developed as an aid to reading. The number of words which can be modified is limited but the principle raises some interesting issues and possibilities. Although symbol accentuation could be used as a limited communication system, it is probably of greater value as a technique that can be used with other graphic systems - especially at the early teaching stages. For example the iconicity (or visual representation) of Blissymbols can be increased though embedding the symbol within a picture of referrent or embellishing the symbol with some aspects of the referrent. Other principles of symbol modification have also been employed in teaching (e.g. ita, IPA, UNIFON Alphabet). Symbol modification through colour coding has also been found to be useful in teaching language structures and in facilitating symbol finding in communication.

These four systems do not exhaust the ideas involved in graphic symbol/system design. For example the Mosman Sounds and Symbols System (Breverton, Burnett & Ivemey, 1979) uses 32 pictographic and ideographic symbols as major conceptual categories within which TO is used for specific referrents. This is an attempt to combine the more basic representational symbols with purely arbitrary or abstract symbols. Other systems use a variation of this strategy (e.g. Blissymbols and expanded rebus). At the extreme end of the abstract continuum are Premack-type symbol systems (Carrier, 1976; Carrier & Peak, 1975; Premack & Premack, 1974) which have limits as communication systems, but may have some syntax teaching advantages.

This overview of graphic symbols/systems raises a number of significant issues. It is striking that none of the graphic systems described were developed as communication systems for the handicapped. This does not necessarily mean that they can not then be used in this way, but what does follow is that they have features which may mitigate against maximal communication value.

At an initial level the use of any graphic system creates an unusual communication pattern. If communication is through a symbol board or screen, the normal patterns of eye contact and use of facial cues is, of necessity, disrupted. There is the danger that both sender and receiver interact with the symbol display rather than with each other. A related problem concerns the almost inevitable slowing of the interaction. This can be partly overcome through phrase-making devices but is still a problem since speed of transmission appears to be a crucial factor in public acceptability of augmentative systems

(Fishman & Baldwin, 1982) and children tend to truncate or abandon use of Blissymbols under pressure to communicate to a teacher (Andrews, 1980).

Principles involved in their construction render some systems specialised to particular uses. For example, the phonic base of some Rebus symbols may be suitable for teaching reading but precludes use with some cognitively impaired individuals because of the cognitive demands. Although many of the principles involved have considerable practical value there are virtually no data illustrating their validity. It is essential that we recognise the confusions which may arise when an individual fails to grasp a principle. For example a child may misunderstand a graphic stick-person symbol like 'run' as a static symbol rather than a movement, or may not comprehend the abstract nature of directional arrows. To some degree such problems should be checked and dealt with in teaching or therapy programmes but rehabilitation engineers and other practitioners need to be sensitised to them and able to devise strategies to circumvent difficulties.

Likewise there are user related problems. For example many mentally and physically handicapped individuals have perceptual problems. These may range from restricted vision, due to problems of postural control or control of the eyes, to more complex problems of central origin such as figure-ground difficulties. This could present problems if the interpretation of the meaning of symbols is dependent on separating elements, for example, in Blissymbolics. Additionally there is strong evidence showing selectivity of attention, often controlled by the salience of elements of a stimulus, which would cause a handicapped individual to miss crucial features of a complex stimulus. Many Blissymbols gain their precise meaning from the form or position of relatively subtle modifier elements. Kalimikerakis (1983) describes data which suggest that mentally retarded children may misinterpret Blissymbols through failure to attend to these modifiers.

These points all reflect the fundamental need for more research into basic issues and, prior to that, caution in use of symbols/systems. However they need to be counterbalanced by mention of several advantages which graphic symbol systems have over the most common alternative augmentative symbols/systems, manual signs.

The advantages include use by individuals who are so severely impaired motorically that use of sign would be limited or impossible. Unlike manual signs, graphic symbols can be routinely accompanied by the written word, so the sender can use one graphic symbol and the receiver can use another (i.e. the written word). Graphic symbols/systems can be easily linked to devices generating synthetic speech, thereby making interaction more natural (although rate is still a critical issue). Likewise graphic symbols/systems are frequently used in combination with nonverbal and/or paralinguistic cues (e.g. gestures and vocalisations), and even speech.

At another level the use of graphic symbols/systems may facilitate the acquisition of syntactic rules through the provision of a medium which allows physical manipulation of sentence forms (Carrier & Peak, 1975; Kiernan, 1983; Kiernan, Reid & Jones, 1982). In essence the use of a graphic symbol system helps the handicapped individual to break down the task of sentence construction into two steps, selection of appropriate symbols and ordering according to rules (House, Hanley & Magid, 1981).

Beyond all of the points it is clear that the value of a system will depend on the needs and abilities of the individual and the purpose of using it. For example, Sigsymbols reflecting sign form may be a valuable transitional step to reading for the child using manual signing but inappropriate for other users. Some systems may have initial advantages that fade at higher levels. This was illustrated by Kuntz, Carrier and Hollis (1978) in using pictographic (i.e. basic rebus) and abstract (Premack-type) symbols with mentally retarded people. They found that their group learned to identify pictographic symbols far more rapidly than abstract symbols. However, when they looked at the transfer from the symbols to TO the advantage disappeared. It seemed much more difficult for some individuals to transfer from pictographic symbols to TO than from the abstract symbols. A similar result emerged in a comparison of rebus and symbol accentuation (Worrall & Singh, 1983).

These results raise several interesting issues. A particular point to highlight is that the two methods shown to be superior are both in practice very limited systems devised for specific purposes. It may be that one way ahead is to devise them for particular purposes with particular populations and individuals. Our major need at this time is not to develop new graphic systems, but to learn more about the particular features and principles of each of the wide variety of symbols/systems currently available and to match the appropriate features and principles to meet each individual's learning and communicative needs. For example one might evaluate symbols/systems against the 23 considerations recently presented by Lloyd and Karlan (1982, 1983, 1984). One also needs to bear in mind that, just as a normal human communication is not limited to one mode or one system for representation, the teaching of, and communication with, communicatively handicapped individuals should neither be limited to one graphic symbol system nor be limited to graphic systems/symbols.

In summary a brief overview of the diversity of symbols/systems and of issues rising from their use has been presented. There is no question of their value to the handicapped or of their potential for development given sensitive clinical use and increasing research. Some advantages of graphic symbols/systems and the use of combined systems were presented. Although there is little need for the development of new graphic symbol systems, there is a critical need to match system features to individual user needs.

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SERVICE DELIVERY FROM A CLINICAL INSTRUCTIONAL PERSPECTIVE

Penny H. Parnes, B.Sc., D.S.P., Director,
Augmentative Communication Service, Ontario Crippled Children's Centre, Toronto, Ontario,
Canada M4G 1R8

ABSTRACT - The model employed by the Augmentative Communication Service of the Ontario Crippled Children's Centre is highlighted. The necessity of embracing both educational and research components as part of an innovative service delivery model is emphasized.

RÉSUMÉ - On décrit le modèle du service de communication élargie de l'Ontario Crippled Children's Centre. On souligne la nécessité de tenir compte tant de l'aspect éducatif que de la recherche dans le cadre d'un modèle de service innovateur.

I OVERVIEW

The Augmentative Communication Service (ACS) is a service of the Ontario Crippled Children's Centre, Toronto funded by the Easter Seal Society (Ontario). It is available to any person utilizing an augmentative form of communication or for whom augmentative communication has been recommended, upon medical referral, or upon application by parents, school or therapist.

The major objective of ACS is to provide support in planning and implementing use of an augmentative communication system. The emphasis of the ACS programme support service is upon helping the person (the facilitator), who is responsible for "facilitating" instruction for the user in their local community.

II BACKGROUND

The past ten years have shown a tremendous increase in interest and expertise in the provision of communication systems and devices to those with major communication problems which preclude functional speech. Persons in this group include those who are congenitally non-speaking, those who have acquired conditions which make their speech non-functional and those with progressive disorders which may lead to a status of being functionally non-speaking. The disorders which may be accompanied by this problem include: cerebral palsy, traumatic head injury, developmental dealy, autism, multiple sclerosis, amotrophic lateral sclerosis, cerebral vascular accident (stroke), etc.

Professionals working with individuals with such problems have recognized the necessity of developing specialists in this field in order to assure that clients are served appropriately by personnel well versed in new developments and sensitive to the unique needs of this group. By-and-large there is now agreement that the field of augmentative communication requires a trans-disciplinary approach rather than being the domain of any specific health care discipline. This was recently reinforced at an international meeting which formed a society focussing on the trans-disciplinary requirements of the field (1) (International Society for Augmentative and Alternative Communication).

The Augmentative Communication Service has evolved from the Blissymbolics Communication Service (BCS) inaugurated in late 1979. The concept of specialized services in Blissymbolics (2) was new to Ontario in 1979. As such, the first year of the BCS' operation saw an emphasis on developing an awareness of the problem among professionals in the province and beginning to formulate techniques for providing services.

From late 1979 through late 1983 the scope of services undertaken by ACS has increased dramatically. Nineteen eighty one saw expansion of services to encompass individuals lacking functional speech irrespective of the systems they required. Systems currently being employed include: manual systems (eg: sign language, Amer-Ind); graphic systems (eg: Blissymbolics, picture systems, word boards); and related technology. The development of communication-related technology has also shown tremendous growth in the past three to four years. This is particularly pertinent as it applies to microcomputers. The development of the Microcomputer Applications Programme (3) has further developed technological applications for this population with subsequent clinical applications by ACS.

III PHILOSOPHY

The ACS, through its original structure and through the on-going opportunity to interact with many professionals in the field and a large number of non-speaking individuals, has developed the following basic underlying philosophy:

(a) Clients seen by ACS are seen with a view to intensive short-term intervention with subsequent shifting of responsibility to those working more directly with the client.

(b) All clients seen through ACS have a designated facilitator who undertakes long-term responsibility for the intervention program and maintains a liaison with ACS.

(c) When possible, the individual's communication system and devices are evaluated in the client's most typical living situation. This often entails extensive outreach activities.

(d) Clients are usually considered as on active follow-up programs so that as new technology is available, as the individual changes, and as the client's environment alters, ACS may intervene again as necessary.

(e) For non-speech communication to be truly effectively used, augmentative communication professionals must promote and undertake public awareness in the client's own environment and in the community at large. This is seen as a basic mandate of ACS.

IV SERVICES PROVIDED BY ACS

Implementation of an augmentative communication system is a complex and multi-faceted process. Included in the process are the areas of:

- communication system(s)
  - graphic (eg: pictures, symbols, traditional orthography)
  - manual (eg: ASL, Amer-Ind, Gestural Code)
  - combination of the above
- communication devices: (eg: manual display, Handivoice, Sharp Memowriter, Microcomputer)
- access to communication devices and systems: (eg: encoding, display design, single switch)
- use of the devices and systems: (eg: interaction patterns)

In providing services to clients in need of these aspects in their communication systems, one must deal with the system(s) as a gestalt. It is inappropriate to try to deal with any single aspect without regard for the whole process.

In providing assessments and program planning for individuals who utilize these systems, one must frequently intersperse various programming activities in a diagnostic fashion, (e.g., it may be necessary to construct a small symbol board in order to assess factors such as, stimulus size, stimulus placement, accessing, functional use, suitability for a particular environment, etc) Hence, one cannot separate assessment from programming in the traditional fashion.

In looking at services provided by the ACS , the following seems to reflect current practices.

(a) Assessment of the individual with respect to:
- various systems
- various devices
- various interfaces
- communication interaction

(b) Consultation to:
- other professionals
- family members
- institutions

(c) Training through:
- orientation sessions
- seminars
- workshops

(d) Outreach to:
- home
- school
- community

V CLIENTS

Since its inception in 1979, the role and scope of the ACS has changed considerably. The range of clients has increased as new populations who could benefit from augmentative communication systems are identified (e.g., ALS patients) and subsequent services sought. The severity of disability of clients referred to ACS has increased greatly. New referrals show much more severe impairment, both physically and cognitively. Some of the developments contributing to this trend include:

- The ACS provides a unique service for clients not available in other centres in Ontario;
- The awareness of augmentative communication is increasing dramatically among rehabilitation professionals resulting in an increase in referrals. Additionally, as professionals in the community become better educated in the delivery of services to this population, the severity of the disability of the clients referred to ACS has increased (i.e., less disabled clients can now be accommodated in the community largely due to educational and outreach activities undertaken by ACS since 1979);
- The recently adopted policies (January 1984) concerning communication aids to be funded through the Assistive Devices Program of the Ontario Ministry of Health will authorize very few clinics in Ontario to prescribe such aids. The ACS as the most advanced clinic in the province will be called on increasingly in this capacity.
- The implementation of Ministry of Education's Bill 82 (access to public education) is steadily increasing the needs of school systems for consultation services regarding augmentative communication to facilitate children attending schools in their local communities.

Clients are referred to ACS from a wide variety of sources. Analysis of referral sources for those clients seen during 1982 (4) are as follows:

(a) Speech Pathologist (from the community and from O.C.C.C.) - 30%

(b) Educational Settings (teacher, principal, special educator, consultant, O.C.C.C. team) - 21%

(c) Medical Personnel (physicians and district nurses) - 19%

(d) Family Members - 13%

(e) Therapists (O.T., P.T.) - 5%

(f) Other (CAS, MR Counsellors, Pre-Voc Program, Group Homes) - 12%

VI EDUCATION FORMATS

The continued need to train, educate and inform facilitators and various community groups about augmentative communication has resulted in continued development and expansion of educational formats within ACS.

(a) BCI Training

ACS, through its personnel qualified as senior presentors by the Blissymbolics Communication Institute, continues to take major responsibility for presenting Blissymbolic Elementary Workshops held in Ontario. This affords an opportunity to interact with many people interested in augmentative communication in the province. This format is encouraged for facilitators and/or professionals working with clients utilizing Blissymbolics.

(b) Additional Training

During 1982, ACS instituted an additional day available for persons already certified in Blissymbolics. This day was developed by ACS to share practical clinical information. The focus of the day is assessment, programming and accessing. It has proven very beneficial in further development of facilitators.

(c) Augmentative Communication Seminar

A one day seminar was developed in 1981, and refined in 1983/84. It is directed toward individuals supporting a communication programme rather than those directly responsible for it. It is presented on a once monthly basis at ACS, as well as elsewhere and is offered to anyone interacting with an ACS client.

(d) Orientation

The continued demand for general information regarding augmentative communication has resulted in the development of an additional training format. A half-day orientation session has been developed and is also made available once monthly for those requesting general information about augmentative communication.

VII MICROCOMPUTER APPLICATIONS

The Microcomputer Applications Programme (MAP) of the Ontario Crippled Children's Centre was formed in July 1982 with support from the Max Bell Foundation. Both the Rehabilitation Engineering Department (RED) and the Augmentative Communication Service provide leadership for this new programme which embraces a multi-disciplinary staff.

The broad objective of MAP is to investigate and implement applications of microcomputers for physically disabled children and young adults. Appropriate research into issues arising from the difficulties that disabled persons encounter in using microcomputers underpins any application. Prime areas of focus for applications include:

(a) augmentative communication for those unable to speak or write;

(b) educational activities that would otherwise not be possible, specifically independent study;

(c) recreational or daily living activities, including art and music;

(d) assessment of perceptual and cognitive abilities; and

(e) assessment of physical abilities.

Research and development activities undertaken by MAP find immediate clinical application within ACS.[5] Recent developments of assessment procedures have vastly improved techniques for providing access to microcomputers for ACS clients. The development of new software and the application of existing software expand the possibilities of utilization of the microcomputer as a communication aid.

Recent activities of MAP and ACS have resulted in the piloting of a facilitator training format for ACS clients for whom microcomputers are prescribed.

SUMMARY

The preceeding highlights of activities of the ACS serve to emphasize the need for clinical service delivery programs to also encompass educational and research efforts as part of their operational plan. Our experiences, as well as those of others [6,7] have reinforced the need to furnish educational formats to those interacting with non-speaking persons. The opportunity to conduct and influence research in the field has also proven to be a major component assuring up-to-date techniques and technology are employed in meeting the needs of this population.

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PSYCHO-SOCIAL PERSPECTIVE

J. Destrooper
Institut de Perfectionnement des Travailleurs Sociaux
Lausanne, Switzerland

TEXT OF PRESENTATION NOT AVAILABLE

TEXTE DE LA PRÉSENTATION NON DISPONIBLE

PROCEEDINGS OF THE 2ND INTERNATIONAL CONFERENCE ON REHABILITATION ENGINEERING OTTAWA
COMPTE RENDU DE LA 2e CONFÉRENCE INTERNATIONALE SUR LA RÉÉDUCATION FONCTIONNELLE 1984

COMMUNICATION INTERACTION BETWEEN AID USERS AND NATURAL SPEAKERS - AN INTERNATIONAL PERSPECTIVE

Arlene Kraat
Queens College, CUNY - Flushing, NY 11367

ABSTRACT - In 1982, IPCAS recognized the need to take a comprehensive look at communication interaction between aid users and natural speakers in an effort to better understand the communication dynamics, the interactional problems, and the training needs in the use of augmentative devices. This special session reports on the findings of that study.

RÉSUMÉ - En 1982, on a reconnu à l'IPCAS la nécessité d'étudier de façon poussée la communication entre les handicapés utilisant une prothèse et les personnes capables de parler sans appareil afin de mieux comprendre la dynamique de la communication, les problèmes d'interaction et les lacunes de la formation nécessaire pour employer les prothèses. A l'occasion de cette rencontre spéciale on rend compte des résultats de cette étude.

INTRODUCTION

In the past decade, technology has provided new communication potentials and capabilities for those with severe communication impairments. In the initial phases of this new field of applied technology, great emphasis was placed on the development of interfacing, techniques, portable dedicated aids and making technical devices available to nonspeakers. Concurrently, various symbol/graphic forms and systems were devised to optimize nonspeech communication. As these systems were placed with children and adults, training focused on the mechanics of aid use, and additionally with children, on symbol identification and syntactic form. Little attention, if any, was given to how these aids were used in natural conversational environments. The assumption was that if a person was provided with a medium, a mode of communication and vocabulary, that communicative use would naturally follow.

In recent years, experienced clinicians and researchers (1,2,3) have begun to look at how manual and electronic communication aids are actually being used by nonspeakers in everyday environments. The observations are unexpected and disturbing. Both manual aids (non-electronic) and sophisticated computerized/electronic communication devices are poorly used and underutilized in natural environments by a large percentage of nonspeakers. This is in sharp contrast to observations of use in special situations, e.g., speech treatment sessions, or in conversation with a particular person (2,3). This realization has spurred further evaluation, concern, and study regarding the use of communication devices in everyday environments and the possible causes of limited use.

In 1982, IPCAS (the International Project on Communication Aids for the Severely Speech Impaired) perceived the need to take a comprehensive look at communication interaction between aid users and natural speakers in an effort to better understand the communication dynamics, the interactional problems, and the training needs in the use of augmentative communication devices. During 1983, important information and perspectives were collected from researchers, experienced professionals, and users in each of the participating countries, Sweden, England, Canada, and the United States for a state of the art report. This special session reports on the findings of a segment of that study (4).

A LOOK AT NON-SPEECH INTERACTION

In the few research studies that have been conducted on communication interaction, some patterns appear and reappear. Generally, the communication balance between the verbal partner and the aid user is atypical. The verbal partner is in a dominant and controlling role, often not expecting a response from the nonspeaker. This control extends to topic selection, the level and length of the interaction, and the degree of participation possible from the aid user. When communication exchanges do occur, these are often characterized by yes/no questions from the verbal partner, or questions requiring a limited response from the aid user. Communication occurs through many modes other than the manual or electronc device. Aided communicators appear in the research studies primarily as respondents and passive partners, and using their communication aids less frequently than anticipated. In general, aid communicators find it difficult to get into the conversation, to stay in the conversation, and to contribute to the interaction in the way they would like to.

There is a segment of the nonspeaking population that is more successful in conversation and interaction than is typically described in the research studies to date. This group of successful aid users cuts across degree of disability, language levels, and age. We are neophytes in our understanding of the differences in device use and interaction between our more successful and poorer aid users. It appears, however, that successful communication interaction between vocal speakers and augmentative communication system users has many unique features that do not necessarily parallel the interaction between two verbal communicators. The means by which specific discourse and pragmatic functions are accomplished appear to be qualitatively quite different.

A CLOSER LOOK AT THE PROBLEM

The first few studies observing aid use in everyday environments tended to put the blame on the verbal partners in the interaction (1,3). For example, the teacher was viewed as not providing an opportunity for the aid user to participate in an interaction; or the wife/attendant was faulted for not taking the time to have an extended conversation with an adult nonspeaker.

Although the communication partner is still seen as a important variable in the interaction process, additional factors have been recognized that also influence and effect the nature and quality of aided communication. Among these are: (1) the characteristics of the manual and electronic devices themselves; (2) the particular strategies used by the nonspeaker in communicating through a device; (3) the training that has been provided; and, (4) the communication demands of a specific context and situation. Any communication interaction is the interplay between the modes available, the abilities and strategies of the nonspeaker, the abilities and behaviors of the verbal partner, and the requirements of the communication situation.

In broadening our view of the variables in the aided communication interaction, we have begun to look at the effects of device characteristics on interaction; to delineate the user strategies that optimize the current technology and lead to more successful interaction; and to re-examine how we have been training device users.

Aid Characteristics - Our current electronic/computerized and manual communication devices have limited capabilities in comparison to natural speech. This does not mean that these nonspeech systems have not contributed greatly to the communication possibilities and abilities of nonspeakers. However, in evaluating aid use and nonspeech interaction, the limitations and constraints inherent in these aids need to be recognized. Observation and study suggest that system characteristics have a direct effect on what is possible, what is probable, and what is successful in communication between aided and natural speakers (5,6,7).

Slow communication rate has been viewed as the primary source of difficulties in aid use. Extensive research and development efforts have focused on interface and acceleration techniques to increase communication device rate. However, optimal rates for a given technique or device are frequently reported with little understanding of how these small increases in rate actually impact on conversation and communication abilities. Until recently, developers have not examined conversational use to gain insights into this question.

There is a growing recognition that device characteristics other than rate may have a large impact on what is possible and effective in conversational use. Some of the system characteristics that are important to study in this regard are: the available vocabulary, what is or is not programmed in flexible language space, characteristics of the synthetic speech output, and the communication outputs in general. Of particular research interest has been the differential effects of manual communication modes, independent electronic aids, vocal vs print output, and non-verbal/speech behaviors alone (4).

User's Strategies - It is becoming obvious that user's strategies and behaviors in communication significantly effect the quality of interaction, both in a positive and negative way. Two nonspeaking individuals can be given the same manual or electronic/computerized device, have equal abilities with the operational features of that aid, and use that device very differently in actual conversational use. Both are attempting to converse within the limitations and constraints of this nonspeech mode, yet one user is superior to the other.

Researchers have recently begun to make an effort to understand how certain communication behaviors are accomplished (e.g., turn-taking; communication repair); and to specify some of the behavioral differences that occur between successful interactants and those who are less successful (4). Of particular interest is a definition of what competency through nonspeech systems of various types might be. If optimal nonspeech interaction can behaviorally be defined, it would be of great assistance to aid developers, researchers, and trainers alike.

Training - Of particular importance is our changing perception of what needs to be trained in aid use. There is a recognition that our training procedures have been partly to blame for poor interaction and aid use. We have not focused on actual communicative use, nor trained within the natural environment. Instead, training has focused on device operation and symbol competency with the expectation that use would naturally occur. It is becoming apparent that specific intervention directed toward interactional use is needed (8). What to train and how to train is currently under study.

The specific strategies and behaviors that maximize augmentative communication interaction remain undefined. It is generally felt, however, that verbal interaction measures can not be used as a model for evaluating and training augmentative communication interaction. This unique mode of communication appears to lend itself to unique rules of interactional use.

Research Methodology - It is felt that many of the methodologies that have been used in past studies of device use need to be re-examined in light of our current knowledge in the pragmatics of communication. We are now aware that study of the aided communicator alone is insufficient. Interaction involves at least two persons, and each of them influences the behaviors of the other. For example, in studying an aid user's lack of communication, or limited communication, it may be obvious that few opportunities were available, or one word responses were appropriate in view of of the verbal person's behavior. Without careful attention to the other half of the dyad, an aid user's communication behavior can not be evaluated appropriately.

Past research efforts have tended to focus exclusively on aid or board use in making statements about communication interaction. This narrow view tends to make the nonspeaker appear more deficit. Researchers are now recognizing the importance of multi-modal communication in this population. They are broadening their concepts of communication to encompass behaviors such as verbalization/phonation, eye gaze, facial expression, hand postures, body tone, and body gestures.

The models against which non-speech communication and use are often examined and compared, are those in vocal to vocal communication. Again, this model and comparison influences research results. Augmentative communication is inferior to vocal speech in conversational use, and research efforts using this model as a means of comparison demonstrate an obvious deficit. It may be more fruitful to study aid use through alternative models, e.g., comparison with the most successful aid users (4).

Several methodologies for studying aid use and interaction are currently being developed and explored by researchers in the field (4). Several difficult and complex methodological questions continue to challenge us. Of particular concern is the reliability and validity of some of our current measures, and how we might capture the information that can be obtained in detailed on-line observation in a more capsulized, experimental context.

SOME PATHS THAT NEED TO BE TAKEN

A central concern for all of us is how to maximize and actualize the communication potentials of persons with severe speech impairments. In discussions with researchers, professionals and users in the IPCAS project, several areas were identified as paramount for future research and exploration (4). Some of these needs and directions are as follows:

1. A greater recognition by device developers and clinicians that communication interaction is the primary goal of technical aid development and application. It is the ability of the nonspeaker to successfully converse in daily living situations that is the mark of our successful intervention and technical advances, not the potential capabilities of an aid in laboratory setting, or a person's skill in aid operation or symbol identification.

2. An exploration of the effects of various aid characteristics on communication interaction in a variety of environments and across listeners.

3. A greater understanding of how successful communication is accomplished using current manual and electronic aids, and which user strategies have a positive and negative effect on interaction.

4. The continued development of training methodologies and models that increase the quality and level of communication for aid users, and the evaluation of these methodologies through positive changes in actual conversational usage.

5. A definition and description of communication competency in interaction between aid users and others.

6. Further exploration of appropriate methodologies for studying interaction through augmentative systems. These methodologies are needed to gain a greater understanding of the communication processes in aided communication, to study differences in aid characteristics and aid users, to isolate problems in communication, and to demonstrate the effects of our intervention procedures.

With a greater understanding of the communication processes in aided communication, and the effects of various aid characteristics and user strategies on additional knowledge about interaction, it may be possible to achieve significant increases in the quality and quantity of aided/verbal interaction with our current technology. Such changes to not necessarily depend on further technological advances.

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SPECIAL SESSION/SÉANCE SPÉCIALE 3

NEURAL PROSTHETICS FOR THE DISABLED/

PROTHÈSES NEURALES POUR LES HANDICAPÉS

Chairperson/Président:

P.H. Peckham
Case Western Reserve University
Cleveland, U.S.A.

ELECTRICAL CONTROL OF BLADDER FUNCTION IN THE PARALYZED

A. Talalla and J. Bloom
McMaster University, Hamilton, Canada L8N 3Z5

ABSTRACT - This presentation reviews the problem of the paralyzed bladder and describes the several electrical stimulation techniques that have been used in an attempt to restore control of bladder function. The present status of electrophysiological artificial micturition in humans and its outstanding problems will be discussed.

RÉSUMÉ - On décrit les problèmes résultant de la paralysie de la vessie et les techniques de stimulation électrique employées pour tenter de rétablir les fonctions normales chez des sujets atteints de cette affection. On parlera de ce qu'il est actuellement possible de faire pour induire la miction artificielle par stimulation électrophysiologique et des problèmes particuliers qui se posent à ce sujet.

Genito-urinary complications remain the leading cause of morbidity and mortality in spinal cord damaged patients (Hackler 1977). Bladder spasticity and hyper-reflexia is often complicated by breakdown of the normal reflex co-ordination between bladder contraction and the relaxation of the bladder outlet at the urethral sphincter. At present there is no completely satisfactory method of managing this condition of bladder hyper-reflexia and bladder/external sphincter dyssynergia.

Attempts to restore bladder function in paraplegia and quadriplegia using electrical stimulation have centered on three techniques-stimulation of the spinal cord itself at the 'bladder centers', direct bladder wall stimulation and more recently, stimulation of the spinal nerves leaving the spinal cord to innervate the bladder. Bladder contraction following stimulation of electrodes penetrating the spinal cord is sometimes associated with disadvantageous expressions of stimulus spread (Friedman et al 1977). Direct bladder wall stimulation is not clinically useful because of major difficulties in excitation-contraction coupling in the human bladder muscle and because of significant pain during the stimulation due to spread of the large excitatory current to surrounding structures (Bradley 1977). Furthermore, neither of these techniques can resolve the problem of bladder/sphincter dyssynergia. Consequently recent efforts have concentrated on sacral nerve stimulation. Brindley (1977) and Tanagho (1977) have shown that stimulation of selected sacral nerves caused satisfactory micturition in experimental animals. Brindley also showed that this stimulation seemed to cause conscious neurologically intact baboons no apparent discomfort nor any deterioration of effect over a period of two years.

Subsequent clinical trials have been somewhat less satisfactory, due primarily to the intermixing of bladder and sphincter efferents in human spinal nerves destined for the bladder. The co-activation of both the bladder and the sphincter has been overcome by an intermittent stimulation strategy (Brindley 1982) which however is unsuitable for some patients (Talalla Unpublished Observation). If all neural input to the sphincter can be blocked, satisfactory voiding of urine can be achieved in the human paraplegic by electrical stimulation of sacral nerves (Tanagho 1983). Unfortunately their means for this neural block is not practical for prolonged clinical application.

Although powerful bladder contractions have been induced by electrical stimulation, the co-activation of the sphincter has made artificial micturition not yet possible and the search continues for efficient, safe and reversible means of relaxation of the external sphincter of the bladder.

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DEVELOPMENTS IN AUDITORY PROSTHETICS

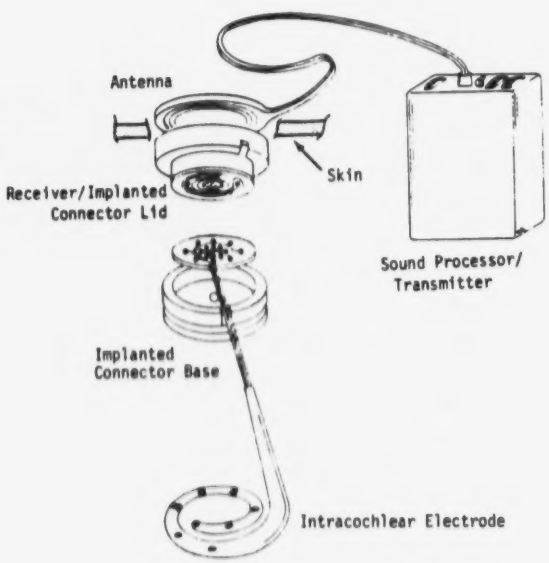
M.M. Merzenich
Coleman Laboratory, UCSF, San Francisco, CA, U.S.A. 94143

ABSTRACT - Basic features of present generation cochlear implants developed for partial restoration of hearing in profoundly deaf patients are described.

RÉSUMÉ - On décrit les caractéristiques fondamentales de la présente génération d'implants cochléaires mis au point pour la restauration partielle de l'ouïe chez les sujets atteints de surdité profonde.

Cochlear prostheses are electrical stimulation aids developed for application in profoundly (totally) deaf individuals. There are probably several hundred thousand possible candidates for such devices in the United States and Canada. Development and application of these devices is based upon the fact that profound deafness is usually a consequence of a total or near-total loss of the sensory transducer cells (the hair cells) of the inner ear; while in the great majority of deaf individuals, there is at least a partial survival of the spiral ganglion neurons innervating the inner ear. Cochlear prostheses are designed to electrically stimulate these surviving first-order auditory neurons, to again generate useful sensations of sound. Some devices have been principally developed for application as aids in lip reading, and to allow for the identification of environmental sounds. Several research and development teams are attempting to employ patterned stimuli that might provide a restoration of hearing of intelligible speech.

The basic components of a cochlear implant are illustrated in Figure 1. The model shown is designed for effecting stimulation of the auditory nerve within the spiral-formed inner ear. Other devices excite the auditory nerve from extracochlear sites in the middle ear. In multichannel devices like that shown diagrammatically, a series of stimulating electrodes are arrayed across the normal zone of neural representation of the sound frequencies of speech, deep within one of the spiral form chambers of the cochlea. In the UCSF implant, for example, the multiple electrode insert is introduced about 23-25 mm into a cochlear chamber about 600 to 1300 microns in diameter, accessing the spiralling auditory nerve array normally representing frequencies ranging from roughly 500-800 Hz to about 5-8 kHz.



Every implant group has developed an electrode or electrode array that is unique in design. Important considerations in their design include: a) mechanical properties allowing for non-traumatic surgical introduction; b) stimulating electrode configurations allowing for appropriately discrete electrical stimulation control of restricted auditory nerve sectors, as required for implementation of sensible mulitchannel devices; and c) biocompatibility of inserts, and for their heavy, long-term electrical operation. Successes in meeting these objectives are highly variable, and, for devices developed by different implant research and development groups, are often not known or documented. Some groups (like the UCSF, Austrian, Australian, and French teams) have constructed hand-fabricated arrays using fine wires and rubber molding techniques; others

(most notably, the Stanford group) have attempted to construct arrays using photolithographic techniques.

Several cochlear implants including the UCSF device employ a connector to couple the electrode array to implanted receiving electronics. There are several purposes for such a connector. It allows for upgrading of receiving electronics as device sophistication increases over time. Just as importantly, it allows for replacement of failed receiving electronics without requiring removal and replacement of an otherwise effective implanted intracochlear electrode array. The most successful implanted connectors have employed a rubber-under-pressure sealing strategy. They have proven to be relatively fail-safe, which is an obvious prerequisite for the use of any connector in this application.

Receiving electronics are also unique in design detail for devices developed by every cochlear implant group. The UCSF group uses 4 parallel, independent RF detectors, allowing for either simultaneous or non-simultaneous stimulation of four electrode channels in a permenent implant device. In a temporary test period (several months in duration), a percutaneous cable is used which allows for access to any combination of 16 contacts (8 bipolar pairs of electrodes). Stimulation can be pulsatile or analog. In the Australian implant, one receiver channel is switched at relatively low rates between 24 electrode contacts; in stimulus sequences, stimulation is of pre-selected bipolar electrode pairs. Devices developed by other groups are coupled monopolarly with a distant common ground (e.g., as in the Utah and Stanford devices), with use of a common intracochlear ground configuration (e.g., as in the French implant), or with relatively widely separated bipolar electrode pairs (e.g., as in the Austrian implant). Multiplexed receiver systems have been developed by research groups in France, Canada, Germany, Belgium and at Stanford. There are substantial differences between all of these model devices, the most sophisticated and functionally versatile of which (Stanford, Belgian, Canadian) have not yet been applied in humans.

Several investigators have temporarily directly accessed implant electrode arrays via a percutaneous plug or cable. The Utah, Stanford and UCSF groups have all applied percutaneous plugs, with mixed success; the UCSF group is now using temporary percutaneous cables, similar in dimensions to widely applied hyperalimentation cannulae. There is strong division in the clinical community as to whether or not permanent use of percutaneous connectors is practicable. At the present time, most research and development groups are working toward implementation of fully implanted multichannel receiver systems.

There is also great variety in the design of applied external sound processor-stimulus coding systems. At least conceptually, these devices have two different stages. In the first, sound is processed for optimal representation across a small number of information chanels. In a second stage, sound information is transformed into a mode appropriate for control of stimulation of the myelinated axons of the auditory nerve array. Again, coding devices in both of these respects are substantially different for every applied device. Some employ pulsatile and some analog stimulation; strategies for "mapping" the dynamic range include manipulation of stimulus durations or rates or amplitudes; some investigators employ variously configured "channel vocoder" speech processors, while others use "formant tracking" speech processors; coupling configurations of processor channel output to the nerve array are unique to each device; among other individual differences.

Of the more than 500 patients implanted with cochlear implants, most devices implanted up to this time have been whole nerve stimulators. Perhaps not surprisingly, the several kinds of single channel devices applied up to this time have also evolved in very different directions, for each research and development team. Two of these devices (House-3M and Austrian) are introduced into the basal cochlea via the round window, using a surgical procedure like that employed to implant longer multichannel intracochlear inserts. (Electrode arrays for the two are, however, very different.) Others (developed by the Austrian and University College London groups) are applied extracochlearly. The House-3M device uses a modulated 16 kHz carrier delivered via a simple implanted coil connected to their single electrode; the Austrian implants use high-fidelity and "frequency balanced" analog stimulation (compensating for differences in loudnesses of evoked sensations as a function of electrical stimulation frequency); the London group employs a coder effecting a voice fundamental extraction and representation.

Given this bewildering variety of devices only occasionally (and almost accidentaly) having common design features; given a lack of comparisons of device efficacies in the same patients, except in a few instances; and given the fact that strategies for describing benefits of device use are also largely idiosyncratic -- it is perhaps surprising that highly significant levels of auditory speech recognition have been recorded with several different forms of cochlear implants. Those include, especially: a) The Austrian single-channel intracochlear and extracochlear implants; and b) the UCSF, Utah, Australian and German multichannel implants. That is, in spite of different electrodes, vocoder-to-nerve array coupling configurations, transmission links and coding devices, significant levels of recognition of unfamiliar speech have been recorded in individual patients in all of these patient series. In addition, improvements in speech recognition with lip

reading have been recorded even with the most primitive of these devices (especially, with the London extracochlear single channel implant).

These clinical results support the conclusion that there is a liklihood that high levels of speech intelligibility will be achievable with application of optimally configured and coupled multichannel cochlear prostheses. It is already clear that the best of present devices are of substantial benefit for at least a large proportion of the post-lingually deaf. In more optimal forms, these devices should be of very important rehabilitative value for a large proportion of the profoundly deaf. One especially important target group are congenitally deaf children. While there are serious implementation problems (among them, head growth and high probability of chronic middle ear infections) presently preventing application of the more sophisticated cochlear implant devices to this population, research efforts now underway should soon open the way for this application as well.

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FUNCTIONAL ACTIVATION OF THE PARALYZED EXTREMITIES

P.H. Peckham, P.E. Crago, R.R. Riso
Department of Biomedical Engineering and Orthopaedics; Case Western Reserve University and
Veterans Administration Medical Center, Cleveland, Ohio 44106

ABSTRACT - Motor prostheses for control of the extremities are now demonstrating the clinical realization of enabling the disabled to regain manipulation and ambulation capabilities. Research and development efforts in six identifiable areas are described.

RÉSUMÉ - Les prothèses motrices pour l'animation des membres démontrent à l'heure actuelle la possibilité clinique de rendre aux handicapés la capacité de manipuler des objets et de se déplacer. On décrit les efforts de recherche et développement dans six domaines différents.

Neural prostheses for control of movement of the extremities provide activation of the muscle by electrical stimulation applied to its innervation. These prostheses can be identified directly with functional neuromuscular stimulation (FNS) as applications to disabled individuals in which the lifetime of the prosthesis will equal that of the user and ultimately will requires implantation of major components of the system. In contrast, therapeutic electrical stimulation frequently employs external hardware and electrodes for delivery of the stimulation, and the duration of use is a much shorter period until a level of voluntary function is reached. This review focuses on identification of the areas in functional neuromuscular stimulation which challenge basic science, Biomedical Engineering, and medical investigators today and in the future.

Research and development in functional electrical stimulation may be divided into six separate but interrelated areas, each of which may be expected to be an integral component of future FNS systems. These areas are: command control, electrode development, open loop activation, feedback control, sensory feedback, and hardware development.

Command control. The means by which the user initiates and regulates the muscle function is through the command control source. The requirements of the source are dependent upon the application, but generally the signal must be easily generated, provide the user with a sense of the magnitude of the command (or command change), have rapid response, not interfere with voluntary movement, and allow the activation of the muscle(s) to be graded and in addition some instances fixed at a constant level. The source of adequate command control signals remains a difficult problem for orthotic/prosthetic systems in general and has received relatively less emphasis in FNS than the considerations of activation. It is well recognized that as the severity of the disability increases, so does the need for the command signals, but the source of potential signals decreases. In the lower extremity, most investigators utilize switches activated by the hands to initiate a sequence of stages of stimulation for generation of the gait cycle. In the upper extremity proportional command signals generated by shoulder or head movement have been most accepted, whereas switch signals and commands generated by the opposite extremity generally have been found to be slow and encumbering. Linking the command process to voluntarily generated synergistic movements of the extremity is a relatively untapped area which may yield significant results in the near future in this very difficult area.

Electrode development. The electrode is the means for introducing the stimulus to the tissue, in all FNS systems today the peripheral nerve (or its terminal fibers) is the point of excitation. Surface and subcutaneous technologies are presently employed, but the general consensus is that implantable systems will be required clinically. Today's standard of implanted electrode technology uses electrodes on (nerve cuffs, intraneural electrodes) or near (intramuscular and subfascial electrodes) neural structures. The design of electrodes which provide safe, repeatable, specific and graded activation is a challenge to be addressed in this session (Hambrecht, 1984).

Open-Loop activation. The gradation and coordination process of stimulation is termed open-loop activation. The process of movement in the extremity requires that each muscle be sufficiently strong and fatigue-resistant with an output force that can be graded. Herein, only two mechanisms can be employed, spatial and temporal modulation. Techniques to coordinate and linearize the open-loop activation process currently underway in the upper extremity are expected to enhance the functionality of present patient systems. Enhancement is achieved by reducing the number of command sites necesary to coordinate complex movements, and by more precisely linking the command control signal to

the output force and position. Such techniques are applicable to both the upper and lower extremity. Nevertheless, the inherent time varying properties of muscle make open-loop control difficult.

Feedback control. The use of closed-loop feedback of the force and position is expected to overcome many of the difficulties encountered in an open loop system. The need for closing both position (length) and force (pressure) loops can be illustrated by a subject grasping a compliant object in which both controlled parameters are simultaneously changing. The challenge lies in designing controllers that are stable over a wide range of muscle properties and still provide adequate response characteristics. Digital controllers have been well characterized in animals, and are now undergoing clinical evaluation in both the upper and lower extremities. The incorporation of feedback control in FNS systems represents another level of complexity in both sensory and processing. This must be offset by the enhanced performance it can provide.

Sensory feedback. The loss of sensation results in an absence of conscious and subconscious awareness for the position of his limb in space and the forces generated by or on the limb. These sensory deficiencies not only limit the functional performance of the limb but can result in devastating trauma to joint and skin tissues. For these reasons, it is essential to provide the user with protective sensations as well as limb position and muscle force information. The source of these sensory signals, potentially may be the same physical variables transduced for the closed-loop system. Techniques to encode and transmit this information to the user are being studied to optimize information transfer rates and ease of discrimination. One technique which appears promising is referred to as electrocutaneous communication and involves the application of coded electrical stimuli to an area of the user's skin in which tactile sensibility is preserved. Research has demonstrated that the utilization of indwelling, subdermally positioned electrodes (as opposed to surface mounted electrodes) can enhance the efficacy and comfort of this sensory feedback technique and minimize the amount of externally worn hardware.

Hardware. The systems employed by patients will ultimately utilize major components that are implantable to perform the command control transduction, the feedback control/sensory feedback transduction, and stimulation processes. One might expect that certain elements would be developed prior to others, and that improvements in microelectronic technology would significantly improve these systems. Thus, one is lead to conceive of a modular system utilizing both implanted and external units, with information transmitted through the skin in both directions. Such an approach enables the system to be upwardly compatible with improved elements. This approach has been taken in our program and major elements are well underway. The implanted units are externally powered slave units which transmit to or receive from an external unit. The external unit contains the computational hardware to perform the desired control, coordination, and regulation functions, and provide for specific tailoring to the individual user.

Functional electrical stimulation promises to provide new means of augmenting motor and sensory function in the disabled. It has applications to many and varied CNS disabilities including cerebral palsy, head injury and stroke, and spinal cord injury. Its use, in conjunction with surgical procedures and orthotics, will lead to exciting developments in restoration of extremity function.

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HUMAN FACTORS IN FUNCTIONAL ELECTRICAL STIMULATION RESEARCH PARTICIPATION

A. Heinemann, R. Magiera-Planey, C. Geist
Department of Psychology and Pritzker Institute of Medical Engineering
Illinois Institute of Technology, Chicago, Illinois 60616 USA

Abstract: An 18 month progress report on a study of the psychosocial aspects of functional electrical stimulation (FES) is described. Results indicate the importance of selecting participants who can provide informed consent and who have acquired coping skills sufficient to deal with research participation.

Résumé: Le rapport décrit les résultats obtenue pour une periode du dix-huit mois d'une étude des aspects psychosociale de FES. Les résultats indiquent l'importance de selectionner des participants qui peuvent fournir un consentement informer et qui ont acquient des habiletés suffisantes afin de participer dans une recherche.

Rehabilitation for persons who are paraplegic due to traumatic spinal cord injury typically emphasizes development of residual skills and adjustment to diminished body functioning (Trieschmann, 1980). The development of technology to achieve stance and ambulation with functional electrical stimulation (FES) may significantly alter rehabilitation objectives and practice. Achievement of greater functional autonomy with FES for some persons who are paraplegic is the goal of several research groups (Brindly et al, 1978; Jaeger & Krajl, 1983; Marsolais et al, 1983; Vodovnik et al, 1981; Wilemon et al, 1970). Continued development promises eventual availability to many persons who are paraplegic.

Such a system can be expected to have a significant impact on the lives of users. The psychological and social effects of participating in a program in which personal benefits can not be guaranteed may be critical to research success; however, possible effects have not been investigated. The life adjustment achieved by research participants is likely to be a critical factor. Careful selection of participants based on a thorough review of previous coping skills and an ability to tolerate uncertainty is in the best interest of potential research participants.

The goals of this investigation were to evaluate a psychological screening protocol to minimize the negative reactions of research participants, to describe the situational contexts associated with various patterns of FES utilization, to describe the psychosocial consequences of research participation, and to help determine patient selection criteria when FES is available for routine prescription. To this end, psychological variables were examined that, on the basis of available literature, were deemed important. These include affective and cognitive states following spinal cord injury, locus of control of reinforcement and attribution of responsibility for injury. This is a progress report following 18 months of data collection.

METHODS

Screening Procedures: The participants in this study were referred by area physiatrists. The screening protocol assessed each participant's ability to cope with the physical and psychological demands of the research, provided information about the project (specifically emphasizing that the goals are research-oriented rather that treatment-oriented) and obtained informed consent. A familial, educational, vocational, and marital history was obtained; mental status was examined (signs of depression, thought process disorders, substance abuse, anger control problems and authority conflicts were sought); and psychological tests were administered.

Screening tests included the Minnesota Multiphasic Personality Inventory (MMPI) to identify persons with thought-process or affective disorders, or authority relation problems; the Shipley Institute of Living Scale to estimate level of intellectual functioning; the Wide Range Achievement Test reading subtest, to assure sufficient reading comprehension to provide informed consent; the Beck Depression Inventory to screen out depressed individuals; and the Acceptance of Disability Scale to assess beliefs that devalue current functioning and self-worth. Persons with signs of a major affective or thought process disorder, substance abuse, low intelligence (less than 70), low reading comprehension (less that sixth grade level), significant interpersonal difficulties, or poor coping skills are likely to be at psychological risk.

Intensive Assessment: The Representative Case Method (Shontz, 1965; Spotts & Shontz,1980) was adapted for this investigation. This is an approach to research that requires the intensive study of carefully selected persons, each of whom is examined in depth over a considerable period of time. This approach is holistic, rigorous, and yields results that reveal underlying psychological processes and that are capable of being replicated by other investigators who study appropriate persons. The study of

natural processes, such as this FES participation study, is ideally suited for investigation by this method. The participants are used as expert consultants because they are in a unique position to report on the effects of and their reactions to the rehabilitative processes under investigation.

Intensive interviews were used to assess each participant's life history, characteristic coping strategies, health history, rehabilitation, adaptation, attribution of responsibility for injury, and personal consequences of FES research selection and participation. Demographic data and information regarding family relationships, education, employment, and religion were collected. Assessment procedures included the Tennessee Self-Concept Scale to quantify changes in self-esteem that may occur during research involvement; the Locus of Control Scale (Rotter, 1966) to determine if attribution of reinforcements changes during research involvement; and selected parts of the AAMD Adaptive Behavior Scale to assess level of independent living skills and changes in skills that may occur during participation.

The Role Repertory Technique (Kelly, 1955) was used to determine significant persons in each participant's life and constructs defined by these roles. Sixteen roles including usual and ideal self (pre-injury, currently and in the future); person with the same kind of disability; best friend; mother; father; brother; sister; intelligent, successful and interesting persons; and a typical patient met during rehabilitation. Each person developed 12 constructs by examining triads of role designators; telling how two are similar and how the third differs from them. To insure that theoretically relevant attributes were rated, 7 standard constructs were included: copes well with adversity, acknowledges limitations and lives life to the fullest, values physical achievement and skill, values physique and physical attractiveness, compares self with others, values self because of intrinsic (personal) assets or characteristics, and experiences emotion intensely. Self-concept assessment and perceived role changes through time are possible with this procedure.

A 48-item Q-sort (Heinemann, 1983) was used to assess four stages of reaction to crises hypothesized by Fink (1967): shock, defensive retreat, acknowledgement and adaptation. Expert opinion was used to select 12 items in each category. Item ratings and congruence between sortings of participants' typical and ideal selves across time provide information on attitudes regarding adjustment and self-congruence.

The Q-Sort, Acceptance of Disability Scale, Depression Inventory, role rep technique, Locus of Control Scale, Adaptive Behavior Scale, and Tennessee Self-Concept Scale were administered after screening was completed, and are readministered at 6 month intervals during research involvement.

RESULTS

Screenings were conducted with 3 new research participants, all of whom appeared sufficiently stable to participate with minimal risk. Only one man demonstrated sufficient muscle response to continue in the program. Intensive psychological assessments were initiated with this participant as well as with 3 men participating in FES studies prior to implementation of screening procedures. Preliminary case summaries are provided for 3 men to illustrate the diverse consequences of research participation.

Case 1: A 35 year old divorced, black male who incurred a gun shot wound resulting in a T5-6 incomplete lesion two and one half years ago. He currently lives with his ex-wife, though he maintains friendships with six other women with whom he has had 12 children in the past 18 years. He graduated from high school, served with an infantry unit in Viet Nam, and worked at a series of skilled trades positions. He describes himself as "going out the world backwards" prior to his injury as he was angry about being laid off work, was dealing in drugs and stolen property, using cocaine and alcohol excessively, and arguing with his wife and women friends over his commitment to them. His cognitive functioning is in the average range of abilities; reading achievement is in the low average range. While no signs of major psychopathology are evident, a low sense of adequacy as a family member, a pleasure-seeking orientation, some suspiciousness and the open expression of hostility are suggested by test results. He appears somewhat impulsive and prone to acting before anticipating possible consequences. In fact, his injury resulted while wrestling for control of a girl friend's gun during an argument with her. He is independent in all activities of daily living.

Q-sort: Initially, he described his ideal self as not expecting a return to preinjury functional levels, as being less anxious, and as being less determined to continue living exactly as before his injury, compared to his typical self. While he described his typical self as being in a stage of defensive retreat, his ideal self was described as being in a stage of adaptation and coping. The 2 initial sortings correlated .39. Six months later, his sortings correlated .37. A principal component factor analysis yielded one factor with all 4 sortings loading at least .53.

Role Rep Technique: Constructs reflect a concern with independence, equity in friendships, assertion, a sense of belonging to a family, personal responsibility and goal-directedness. Correlations between typical and ideal selves on 17 nonredundant constructs were .68 in the past, .95 at present, and .85 in the future. This indicates a perception of greater self-congruence at the time of assessment and in the future than in the past. Characteristics common to his typical and ideal selves include being self-reliant, opinionated, active and goal-directed.

Summary: This participant seems to experience a conflict between good and evil intentions and to strive to be a saint in a world ot temptation. He lacks an affective vocabulary, desires affection, and uses his sexuality success-

fully to achieve intimacy. However, committment to one woman seems frightening. He establishes his self-esteem by seeking others' admiration and has done so successfully in many settings including this research project by being a model subject. He perceives his disability as retribution for past sins and as benefiting him by forcing him to live slower and more deliberately. His disability has led to strain in social relationships and resulted in disappointment with friends who behave in an untrustworthy manner. Reciprocity in relationships is an issue for him. He coped with stressful situations before injury by taking physical action, a course not as open to him in a wheelchair. He perceives FES as a way of achieving greater independence, as restoring his self-esteem as a man, and as something he can do to help persons who are paraplegic. He experiences reflexogenic erections with FES and has used this phenomenon to achieve intercourse. He takes pride in being an FES "pioneer." He copes well with disability-related limitations but wants to be more mobile. He perceives FES as a way of achieving this goal.

Case 2: A 35 year old married Latino male injured at the T5-6-7 level in a hang gliding accident on Christmas Day. He lives with his wife and four children in a working class, Hispanic neighborhood. He completed junior high school and worked as a meat cutter for 13 years and then as a tradesman. He was unemployed when injured. He terminated his participation in the psychological assessment as he approached the second anniversary of his injury. Considerable emotional turmoil was experienced as he recalled his accident. Evidence of increasing alcohol use and depression was monitored and the suggestion to seek counseling was made. He appears to be grieving the loss of functional capacities and social participation. However, he is substituting new leisure activities, becoming more involved with his family, and planning for the future. He described dancing, love making and his children as his three passions in life. He reported feeling abandoned by friends who could not deal with his disability. He paints as a way of coping with life misfortunes as this restores a sense of creativity.

The limited information available from him suggests he is of average intelligence and functioning in the low average range of academic achievement. A low frustration tolerance, ineffective hyperactivity, impulsiveness, and anger are suggested by MMPI results. The largest discrepancies between ideal and typical self Q-sortings were on items in which his ideal self is more in control, plans to keep pre-injury goals and values, feels the world should take care of him, and is better off than he was pre-injury. His sortings correlated .30.

Case 3: A 42 year old divorced, black male injured seven years ago at the T3 level as a robbery victim by an unknown assailant. He lives alone in a comfortable high-rise apartment, completed two years of college, then worked as a barber and hair stylist for 15 years until his disability prevented him from continuing this work. Reading, viewing films and plays, and socializing were described as primary leisure time activities. He lives comfortably on social security disability insurance, real estate investment income and a large settlement from a lawsuit brought against the parking lot owner where he was injured.

He appears to be of average to high average intelligence and to possess a high average level of academic skills.

MMPI: No evidence of major psychopathology was found. While personality functioning appears stable, he tends to deny the existence of negative feelings as a way of minimizing interpersonal conflicts. He is adept at making positive social contacts, but may be somewhat dependent on others for approval. He is prone to expressing frustration and anger towards inanimate objects rather than toward people. For example, when his muscles were not responding to FES, he expressed disappointment in the equipment, anticipated eventual muscle response, and discussed finding other research programs that might benefit him more. He is independent in all activities of daily living, and has an active social life.

Q-Sort: This participant consistently endorsed items reflecting adaptation to injury when describing his typical and ideal selves initially and 6 months later. His typical and ideal self sortings correlated .78 initially and .70 6 months later. A principal component factor analysis produced a single factor on which the 4 sortings loaded at least .81.

Role Rep Test: Constructs reveal a desire to attach to and seek support from other people, to plan for his future, and a concern about personal growth.
Correlations between initial typical and ideal self ratings on 19 constructs were .83 in the past, .76 currently and .89 in the future. A similar pattern was seen 6 months later with correlations of .97, .61 and .93, indicating less perceived congruence between typical and ideal selves when assessed than perceived in the past or expected in the future. Characteristics common to both his typical and ideal selves currently are a concern about himself, family and others, and being active, mature and goal-directed.

Summary: Reciprocity in friendships, personal responsibility and planning for long-term goals are issues for him. This contrasts with what he described as a more short-term, pleasure-oriented past. He described frustration resulting from reduced mobility and impaired sexual functioning as a primary psychological consequences of his disability. While having fewer girlfriends, being less socially active and not working are negative changes, he reports being closer to family and supportive friends, being more introspective, and as striving for greater maturity as positive changes. He copes with an uncertain future by maintaining what appears, to the investigators, to be an unrealistic expectation of increased functional autonomy without being able to explain how such an end

could be reached. Research involvement seems to be a way for him to maintain hope of a more functional future.

Discussion of Results

Several conclusions are suggested by the data.

1. Screening procedures serve to provide participants with information on FES and the limited personal benefit that is likely. However, their reasons for participating typically are based on a hope of improved functional capacity. While some participants perceive FES as enhancing an already satisfactory life, at least one person sees FES as a way of salvaging a bleak future. Little change in participants' expectations was seen despite the provision of information. All participants exhibit the capacity to tolerate the certainty inherent in this research.

2. Selecting participants without psychological screening resulted in the acceptance of one person who is vulnerable to depressive episodes which may be exacerbated by poor muscle response to FES. The need for psychological screening, intensive psychosocial assessment, and provision for referrals is apparent.

3. Persons who have had a number of years to learn to adapt to their physical and social environments, to adjust to their new status, and who do not value physical functioning as a prerequisite to a satisfactory life are least likely to experience problems as a research participant. They are more likely to have established a reason for living and to not place all hope for a satisfactory life on FES-caused improvements in functioning.

4. The opportunity to compare physical performance by observing other persons in the lab may intensify feelings of inadequacy in persons who place much hope in FES. Self-comparisons are a less risky way for persons to monitor the physical effects of FES.

5. All participants have expressed appreciation for the opportunity to discuss their life experiences with the exception of Case 2. Appropriately screened persons are less likely to experience disruptive reactions to their participation and to maximize the effectiveness of FES technical studies.

Continued investigation of the psychosocial aspects of FES research is planned to minimize psychological risks to participants. Monitoring participants' adaptation during FES research will lay the foundation for patient selection and FES prescription should it become routinely available. Prospective investigation of the relationship between participants' life histories, coping styles, acceptance of disability, and FES utility on a case by case basis provides a unique opportunity to determine the psychological, social and situational characteristics that influence FES utilization. The opportunity to grieve the loss of body functioning, an experience typically expected to be a prerequisite of successful life adjustment, may not be required, or in fact, may be detrimental to successful use of FES.

At this time, we can only speculate about the kind of person who is suited to immediate or delayed training in FES to achieve stance and gait. It may be that immediate prescription and training for all physiologically appropriate patients results in the fewest complications and rapid acceptance of FES technology as is the case with prostheses use following amputation. Perhaps conventional skill development emphasized by current rehabilitation practices followed by FES prescription will result in optimal utilization. Development of a costly technology that will be quickly abandoned by disappointed users is clearly not in the best interest of patients, health care providers or rehabilitation agencies. Identification of personal and situational characteristics associated with FES utilization and amelioration of FES technology problems could minimize waste of financial resources and personal investment and provide a basis for FES prescription in the future.

Acknowledgements

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OVERVIEW AND FUTURE DIRECTIONS

F. Terry Hambrecht, Head, Neural Prosthesis Program
National Institutes of Health, Bethesda, Maryland, U.S.A. 20205

ABSTRACT - The key to more sophisticated neural protheses is the interface between electrodes and neural tissue. Research efforts are concentrating on new materials and electrode designs to permit safe, selective stimulation over long periods of time.

RÉSUMÉ - L'interface entre les électrodes et le tissu nerveux est l'élément-clef clef qu'il faut étudier pour perfectionner les prothèse neurales. Les travaux portent essentiellement sur de nouveaux matériaux et de nouveaux modèles d'électrodes avec lesquels on cherche à produire une stimulation sûre, sélective et prolongée.

Neural prostheses rely on direct interfaces with neural tissue to replace or supplement neurological function. This interface is one of the principal keys to success or failure. Considerable effort is being expended to develop safe and reliable methods of stimulating neural tissue and conversely to develop methods of detecting neural signals for control of external devices. If the present efforts to develop interfaces are successful, we can anticipate not only the widespread clinical availability of bladder evacuation, auditory and motor prostheses, but also prostheses for incontinence, impotence, lack of tactile sensation and possibly even blindness.

Presently available neural prostheses have large electrodes and activate large numbers of neurons in synchrony. This is permissible when the primary goal is to simply trigger an event such as a heartbeat with a cardiac pacemaker or a diaphragm contraction with a phrenic nerve stimulator. However, normal neural function relies on spatiotemporal patterns of neuronal activation. Rarely are groups of neurons activated in synchrony. If prostheses are to become more physiological, the electrodes must be reduced to the size of the neurons and must be placed as closely to the neurons as possible. This must be done with minimal tissue damage during electrode insertion and during use of the electrodes.

To minimize electrode insertion trauma, the primary requirement is to minimize the cross sectional area of the electrode. A conical tip is less injurious than a blunt tip but there is presently controversy as to whether the cone should have a long slow taper or whether there should be a rapid taper followed by a section with uniform cross sectional area. The latter design is felt by some to reduce tissue compression during insertion.

Once inserted, the electrodes should move with the tissue rather than relative to the tissue. Designs that involve fixation of rigid electrodes to bony structures when the soft tissue around the electrodes moves relative to nearby bones are doomed. Various connecting lead designs including weaves, coils, conducting polymers and conducting beads within flexible tubes are being investigated.

The electrodes must be made of biocompatible materials. This includes both the outer insulation coating and the exposed electrode contact. Many commercially available polymer insulators contain additives such as plasticizers and fillers which can leach out and cause tissue necrosis. The medical grades tend to be purer materials without leachable ingredients. At the present time, the most promising insulators to supplement the well-known silicone elastomers are the poly-p-xylylenes and the polyimides. Neither are particularly new materials, but they are now being characterized and optimized for biomedical applications.

The exposed electrode contact materials have historically been metals. In motor prostheses, stainless steels have been preferred for conducting leads and electrodes because of their resistance to breakage during movement. In other applications, noble metals have been used because of their resistance to corrosion. With the rapid demise of the mechanical watch and its mainspring, we must look elsewhere for industrial research on small diameter, flexible and mechanically fatigue resistant metals. More encouraging has been the development of new corrosion resistant contact materials. The most promising is activated iridium oxide which is able to pass charge from the metallic electrode lead into the ionic environment of the extracellular fluid by valance transitions within the oxide (1). Pure iridium is known to be a biocompatible material, but studies to determine the biocompatibility of iridium oxide have just been initiated. The crux of the matter is that once we have electrodes that are biocompatible and can safely pass large amounts of electrical charge per unit of surface area, we can then shrink the size of the electrodes to the size of neurons and achieve one of the two requirements for selective stimulation. The second requirement, the ability

to place the electrodes directly next to the neurons, is also well on the road to solution. Interestingly, most of this work is being done by neurophysiologists who want to know the electrical behaviour of individual nerve cells over long periods of time. They have designed chronic recording microelectrodes which are capable of recording the electrical activity of single neurons for several years (2). To do this, the microelectrodes must be within about 200 microns of the neurons and must not move relative to the neurons. The sophistication of these electrodes has also increased. Present designs are utilizing photolithographic techniques to place up to 10 electrode contacts on a single probe (3). Eventually, these probes will also contain all amplifiers and multiplexing electronics so that the activity recorded from all the contacts on the probe can be transmitted out of the nervous system on a single channel.

These techniques promise to provide new sources of command and control signals for motor prostheses.

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SPECIAL SESSION/SÉANCE SPÉCIALE 4

CURRENT CONCEPTS IN SPINAL CORD REHABILITATION/

TECHNIQUES COURANTES DE RÉADAPTATION DE LA COLONNE VERTÉBRALE

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S. Reger
University of Virginia, REC
Charlottesville, U.S.A.

KINEMATICS OF THE THORACO-LUMBAR SPINE

J. Koreska, F. Miller and C.F. Moseley
Hospital for Sick Children, Toronto, Canada M5G 1X8

ABSTRACT - Spinal deformity secondary to muscle dysfunction or cord injury is a significant clinical and rehabilitation problem. Quantitative measurement of static and kinematic behaviour of the thoraco-lumbar spine provides essential information about the prognosis of a structurally unstable spine. Prophylactic treatment, including surgical stabilisation, offers clear advantages to the patient. Evaluation of surgical management techniques and hardware eliminate significant shortcomings found in conventional instrumentation.

RÉSUMÉ - La déformation de la colonne vertébrale consécutive à un dysfonctionnement musculaire ou à une lésion de la moelle épinière constitue un problème important du point de vue clinique et du point de vue de la réadaptation. Les mesures quantitatives du comportement statique et cinématique de la colonne thoracolombaire fournissent des renseignements essentiels sur le pronostic d'une instabilité structurale de la colonne vertébrale. Le traitement prophylactique, y compris la stabilisation chirurgicale, offre des avantages certains au malade. L'évaluation des techniques chirurgicales et du matériel éliminent des défauts importants que l'on trouve dans les instruments classiques.

Spinal disorders associated with Duchenne's Muscular Dystrophy (DMD), a condition resulting from gradual wasting of muscle and strength, are classified as paralytic. Our clinical experience with paralytic spinal deformities is derived to a large extent from this group of patients. They represent an excellent source for the study of spine mechanics and assessment of methods for rehabilitation, or habilitation, of victims of spinal disorders secondary to paralysis. The paralysis may be the result of muscle dysfunction or it may be caused by injury to the spinal cord.

Regardless of cause, lack of adequate active muscle support leads to deformity and structural collapse of the spinal column (1). The deformation process involves bending as well as coupled axial rotation (twisting) of the spine, with associated pelvic obliquity, resulting in poor sitting posture and often intolerable discomfort caused by excessive pressure in the seated area. Pressure necrosis may render the individual unable to maintain a sitting position.

The goal of our treatment is to protect the unstable spine against collapse. The term "paralytic" is both inadequate and misleading in this context. In spite of their disability, these children are extremely active in their electrically powered wheelchairs and the spine is constantly moving - and deforming.

To properly document this dynamic deformation process, we use a computer-aided approach based on Antero-Posterior (A-P) and Lateral x-ray films. The two film images are digitised in turn and combined into a three-dimensional (3-D) numerical matrix for automated manipulation and calculation of curvatures and other deformities (2). Three orthogonal views, A-P, Lateral and Apical, are presented graphically to help in the interpretation of the true shape of the spine (Fig.1).

While this method of analysis is useful in determining some of the more complex patterns of deformation occurring in a patient over a long period of time, it is still a static analysis. In this presentation, we will discuss some aspects of spine kinematics, that is, mechanical behaviour associated with motion. Specifically, we have studied the changes which occur when a lateral curvature is imposed on the spine of a seated person. We also monitor changes which occur as a result of surgical stabilization, both short-term and long-term. Kinematic behaviour has significant clinical implications when predicting spinal collapse and in the assessment of surgical techniques and hardware.

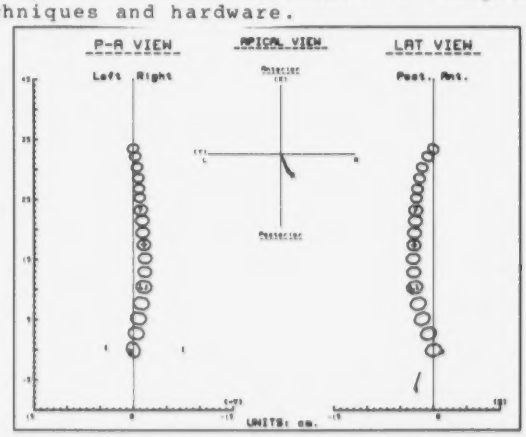

Fig. 1. Plot showing A-P, Lateral and Apical views of a deformed spine.

Sixteen normal subjects and thirty patients with DMD were examined. The patients selected had little or no apparent spinal deformity. Each individual contributed three A-P views of the spine, one in the normal upright sitting position and one each with the spine bending to the left and to the right. A positioning device was used to ensure standardized alignment of pelvis and shoulders (3). Lateral bending views were obtained after a 30 degree lateral wedge was inserted in the seat of the positioning device. The films were digitised and analysed using a computer-aided technique capable of determining vertebral rotation with an accuracy of two degrees (4). Only A-P projections of the spine are required for analysis of rotation. Two examples of the clinical application of the method are shown in Figures 2 and 3.

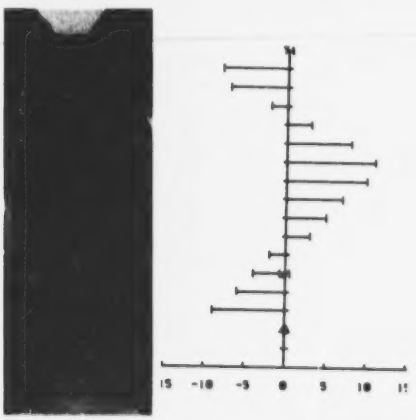

Fig. 2. Example of rotation measurement on x-ray film of patient with idiopathic scoliosis. Absolute rotation is plotted using the fourth lumbar vertebrae (L4) as the reference vertebrae (zero rotation).

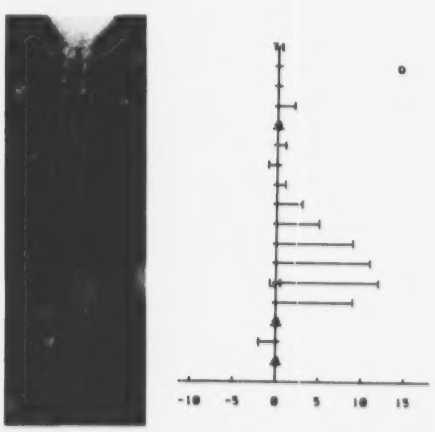

Fig. 3. Example of rotation measurement using x-ray film of patient with paralytic scoliosis. Absolute rotation is plotted using L5 as the reference vertebrae.

PARALYTIC SPINE KINEMATICS

Vertebral rotation was assessed as the change in segmental rotation which occurred when the spine moved from its neutral position to the end of the bend.

In the normal subjects, we observed coupling which was anti-directional in the lumbar spine, i.e. bending to the left caused the spine to rotate to the right and co-directional in the thoracic spine (Fig.4). This, however, was not the case in the paralytic spines. Here, there was a general lack of consistency in the coupling mechanism with large variations in segmental coupling behaviour (Fig.5). Even in the neutral position of the spine, we observed significant segmental rotations not seen in the normal spines studied.

A straight, perfectly aligned spine appears to be an idealized condition. All the clinically normal spines studied had minor defects in coupling behaviour and irregular patterns of segmental rotation in the straight upright position. However, the irregularities involved small segmental rotations when compared to the paralytic spines studied, and were generally in alternating directions from segment to segment. Thus the overall effect of the imperfections was a balanced spinal column. When bending to the left or right, the normal spine irregularities vanished into a consistent pattern of coupling.

In the paralytic spines, however, the noticably larger initial segmental rotations increased with lateral bending and coupling was either inconsistent or completely absent.

These observations suggest that muscle activity is a significant factor in normal spine kinematics. We also concluded that the facet joints are not involved directly in the coupling process, but serve as blocks setting maximum limits for segmental rotation, possibly to protect the spinal cord.

Lack of consistent coupling in the paralytic spines studied, most of which were mildly deformed, suggest that the coupling mechanism is an important aspect of normal as well as abnormal spine behaviour. In the DMD patients studied with long-term follow-up, a lack of consistent coupling preceded rapid progression of the deformity leading to structural collapse of the spine.

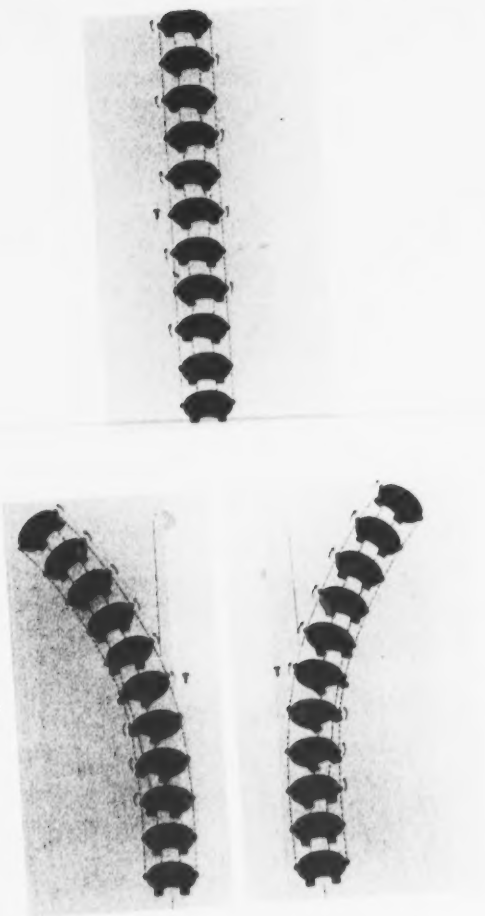

Figure 4. Graphical representation of coupled motion in a normal spine bending laterally. Segmental coupling is anti-directional in the lower (lumbar) region and co-directional in the upper (thoracic) section.

Figure 5. Illustration of irregular coupling of axial rotation with lateral bending in an unstable paralytic spine. Coupling pattern is inconsistent and segmental rotations are more pronounced.

KINEMATICS OF THE 'FUSED' SPINE

There is a growing trend toward surgical management of our patients with paralytic scoliosis. At first, the established approach using a single Harrington rod with hooks at the sacrum and upper thoracic levels respectively, was used in combination with posterior fusion of the spine segment spanned by the rod and hooks. However, the rod broke within a few months of service and a rapid transition was made to use two rods instead of one. While this eliminated catastrophic rod failure, it often resulted in disengaging of one of the two lower hooks at the sacrum when the pelvis re-established its pre-op oblique position. Consequently, pelvic obliquity and lumbar scoliosis increased. Furthermore, the Harrington method did not allow complete correction of the deformity, including axial rotation.

Initially, the paralytic deformity is isolated to the lumbar and lower thoracic spine segments. The Dwyer procedure offered an excellent method for correcting this deformity, particularly where significant vertebral rotation was involved. But the limited length of segment stabilised soon resulted in deformity of the untreated segments both above and below the instrumented and fused segment.

Regardless of instrumentation used, it is essential that as much length as possible of the thoraco-lumbar spine is stabilised from the sacrum to at least the level of the fourth thoracic vertebrae (T4).

In 1978 the Luque method was introduced into the surgical management of paralytic spine deformity at our Hospital. Segmental support, attaching each vertebrae to two pre-contoured L-shaped rods, is a very efficient way to restore normal shape of the spine. However, this instrumentation offers no resistance to vertical shift of the rods caused by lateral tilting of the pelvis. Nor does it prevent axial rotation of the spine and hardware.

In the thirty paralytic patients treated using L-rods, all showed signs of instability within a few months of their operation. Vertical alignment of the spine was generally good, but increased pelvic obliquity and in some cases significant spinal rotation, resulted in increased deformity and poor sitting balance within six months of the operation.

Our solution to that problem is the Unit rod, implemented in 1981. Two paralytic spines were stabilised using this method and monitored for at least one year (5).

Residual movement of the pelvis in the sagittal plane caused brief discomfort during the first few months after the operation. Also, pelvic tilt in the A-P direction was less than ideal and difficult to change. As a result, the Unit rod has been extended into the pelvis to provide complete and rigid fixation of both the unstable spine and the pelvis in its proper anatomical position for comfortable and balanced sitting.

SUMMARY AND CONCLUSIONS

Kinematic behaviour of an unstable spine is investigated using conventional x-ray film images. Three-dimensional analysis of spine geometry is done with the aid of a desktop computer/digitiser system. Coupled motion of the spine is quantified using A-P views of the spine in neutral and lateral bending postions.

Paralytic spines show abnormal coupling behaviour before a clinically significant deformity appears. Analysis of coupling provides indication for the need and timing of prophylactic surgical stabilisation. The implanted instrumentation used must provide complete support to the pelvis and thoraco-lumbar spine.

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NON SURGICAL MANAGEMENT OF PATIENTS WITH SPINAL CORD INJURIES

W.S. El Masri, F.R.C.S., ed., H.L. Frankel, F.R.C.P.

ABSTRACT - Rationale and principles of the non surgical management of spinal cord injuries and their effect on the systems of the body are presented.

RÉSUMÉ - Les raisons et les principes de traitement non-chirurgical des lesions de la moelle epiniere et leurs effects sur les systemes du corps sont presenter.

The initial management of spinal cord injuries remains controversial for decades following the pioneering work of Guttmann. Although our knowledge of the anatomical, physiological and biochemical changes following spinal cord injuries is on the increase, many un-answered questions remain.[1] The reproducibility of spinal cord injury in the controlled environment of the laboratory situation is difficult;[2] extrapolation to the clinical situation may be misleading.

RATIONALE OF NON-SURGICAL MANAGEMENT OF SPINAL CORD INJURY PATIENTS.

1. Patients are poor surgical risks.[3,4] Their vasomotor controls are inefficient and their respiratory reserves are deficient.

2. Preservation of remaining neurological functions.

   i Most of the damage to neural tissue occurs at the time of the accident.

   ii Incomplete spinal cord injuries have a tendency to improve.[5-6-7]

   iii There is evidence that decompression by laminectomy could result in meurological deterioration.[8]

   iv There is no evidence that surgical interference will improve the neurological outcome.

3. Achievement of Stability

   i Bony healing and stability of the vertebral column are a natural occurence with conservative management in the majority of cases.[5-6]

   ii Functional stability is best achieved by union at one or two units of motion.

   iii Long segmental fusion can interfere with spinal, thus patients mobility.

4. Avoid raising patients hopes for neurological recovery. These hopes cannot be gratified by surgical interference.

PRINCIPLES OF MANAGEMENT OF PATIENTS WITH SPINAL CORD INJURIES.

1. Resuscitation

   Ensure patient airways with least mobility to the spine. Ensure a venous line taking care not to overhydrate nor underhydrate patients as they can go into heart failure or renal failure easily.

2. Diagnosis

   In the conscious patient loss of sensation and voluntary muscle power are usual indications. A high degree of suspicion is needed to avoid missing the diagnosis in the unconscious patient following head injury. The presence of hypotension bradycardiac diaphragmatic

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breathing and priapism should further heighten suspician. A cervical spine x-ray is always advisable in the unconscious patient with head injury.

Double injuries of the vertebral column at different levels occurs in about 5% of cases.

3. Realignment and stabilization of the spine:-

Realignment of the spine is easily and safely achieved in the first few hours following injury before cord oedema and soft tissue oedema settle (provided the clinician is experienced).

Cervical Injuries:-

Skull calipers are inserted for all flexion injuries of the cervical spine.

Value of skull calipers:-

- Help during postural reduction of compression and flexion fractures with and without dislocation.
- Help maintaining reduction. They are usually left for a period of 6-10 weeks bony union is achieved.
- Help maintaining the spinal cord in extension thus avoiding tension on the cord.[9]
- Help assist postural nursing of the patient.

Reduction with skull traction and Manipulation:-

A combination of skull traction and manipulation without an anaesthetic allows the monitoring of neurological functions. Slow increasing traction in 45° flexion of the head results in fatigue of the paravertebral and paraspinous muscle, thus allowing the use of smaller doses of muscle relaxants. (Small doses of diazepam 5-10 mg), further relax the musculature of the neck with lesser effect of respiratory depression. We advise starting with ten pounds at 10 minute intervals. Manipulation is attempted at 20-25-30 lbs. An increase to 35 lbs is rarely needed. The weights are reduced over a half hour period. The procedure should be discontinued with any signs of neurological deterioration. This procedure is contra indicated in extension injuries of the cervical spine. Extra care and less weights are needed when both the anterior and posterior elements of the spine are disrupted. An inexperienced clinician can ruin the quality of life for a tetraparetic patient. An x-ray of the cervical spine is taken at the end of the procedure and on the following day; it is then repeated at 2-3 weekly intervals.

Dynamic views (Flexion, Extension, x-ray films) are taken when bony healing is thought to be achieved. Active neck extension exercises are encouraged for 3-5 days prior to mobilization.

Thoracic Spine injuries:-

These are usually stable. Postural management for a period of 4 weeks for the upper 4 dorsal spines with an additional week for each level below, down to D9.[10]

Dorso-Lumbar Spine Injuries:-

Postural reduction for flexion injuries of the dorso-lumbar spine without displacement is usually successful.

Closed reduction with traction and manipulation is attempted when there is displacement with sensory sparing over the iliac. chest. As a rule the earlier the procedure is undertaken the easier it is achieved. Higher doses of diazepam (20 mg) are needed than for the cervical spine.

4. Management of Associated Injuries:-

Upper limbs:-
Are relied upon for ambulation in calipers and wheel chairs. Fractures are treated so that best healing and most accurate alignment is achieved. They often need plating.

Lower limbs
The line of management

(conservative or surgical) will depend on the expected neurological outcome.

Should surgery be considered, fixation with plates is preferred to intramedullary nailing as the later procedure does not stop rotation at the site of the fracture during nursing.

Intra Abdominal Catastrophies:-

Delayed neurogenic ileus is often concommitent with spinal cord injuries at all levels. A retroperitoneal haematoma associated with a dorso-lumbar lesion could prolong ileus. Patients with complete spinal cord injuries are not allowed food or drink for 48 hours or longer until the bowel sounds are audible.

A nasogastric tube is often necessary to avoid respiratory embarrassment. Shoulder tip pain and increase in growth measurements are often the only signs of an intra-abdominal catastrophy.[11]

5. Management of the Cardio-Vascular System:-

Cardiac arrests in tetraplegic patients is a common course of death in the early stages. Bradycardia usually preceeds cardiac arrest. Excess vagal activity in the absence of sympathetic activity during the stage of neurogenic shock is the probable explanation.[12] Stimuli precipitating cardiac arrest are hypoxia, Tracheal stimulation and Hypothermia. Oral prophylactic anticoagulants are commenced as soon as the clinician is satisfied that there are no signs of internal bleeding (usually 48-96 hours following injury).[13] Subcutaneous heparin alone does not always prevent death from pulmonary emboli.

6. Management of the Respiratory System:-

Good physio-therapy ensures patent airways and adequate oxygenation in patients without associated injuries to the respiratory tract. Patients with isolated spinal injuries at the level of C5 and below rarely need tracheotomies. Vital capacity and blood gases measurements are good indicators of the patients respiratory state.

Indications of tracheotomy:-

1. Vital capacity below 600 cc associated with fall in PO_2 below 60 m Hg.
2. Ascending C5 lesions.
3. Shocked Lung.
4. Flail chest.
5. Patients with C_4 lesions and above.

Tracheal stenosis following tracheotomy in a tetraplegic patient is a potential respiratory disaster.

7. Management of the Urinary tract:-

Intermittent catherization with the non touch technique is initiated as soon as the patient's general condition is stable; usually 24-96 hours following injury and at an interval of 4-8 hours. Over distension of the bladder should be avoided by increasing the frequency of intermittent cathertarization rather than restricting fluid intake. The patient is encouraged to stimulate detrusor activity by suprapubic tapping and crede and is weaned off cathetarization when residual volume falls to below 80 cc and the voiding vesical pressure is satisfactory.

Advantages of Intermittent catheterization over indwelling catheter drainage;-

1. Decrease in incidence of bladder infections and stone formations and their effect to the upper urinary tract.
2. Preservation of the reservoir function of the bladder.
3. Avoidance of a myriad of urethral complications such as periurethral abscesses fistulae and diverticilae.

An intra-venous pyelogram is performed 6-10 weeks following the injury unless there are some indications for one prior to that time.

Delayed bladder outlet surgery is required for about 20% of the patients.

Potential complications of bladder outlet surgery are interference with erectile potency and retrograde ejaculation.

Regular outpatient follow up . including I.V.P. at 1-2-3 yearly intervals are required for the rest of the patient's life.

8. Management of Bowels:-

Bowel training to achieve a set pattern of regular evacuation. This is initially undertaken by the nursing staff and may subsequently be carried out by the patient himself.

9. Pressure sores are one of the most frequent avoidable complications. They expose the patients to additional hazards of septicaemia and cross infection. Further more the management of these sores is very costly. Treatment consist of:

   i. Surgical debridement

   ii. Nursing care

   iii. Primary excision and direct closure. Split skin graft is sometimes required in a large sore prior to primary excision and direct closure.

Primary excision and direct closure following shaving or osteotomy of the underlying, often infected bone, is a simple procedure and can be repeated many times.[14] A paraplegic or tetrapaedic patient is a potential recurrent pressure sore candidate.

10. Managment of the Musculo-Skeletal system:-

Prevention of contractures and heterotrophic calufication is vital to preserving mobility. This is achieved by adequate, regular informed physiotherapy.

11. Psychological support during the various stages following the injury.

The initial reaction is usually fear followed by severe depression associated later on with anger. Most patients eventually accept at least partially their disability.

Psycho-sexual counselling is almost always needed and plays an important role in the management of the patient.

Experience has shown that management of patients with spinal injuries is best achieved in a specialized centre affording total patient care from the day of the injury to the rest of the patient's (or doctor's) life.

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W.S. El Masri, F.R.C.S. ed,
Consultant Medical Director,
Midland Spinal Injuries Centre,
Robert Jones & Agnes Hunt
Orthopaedic Hospital,
Oswestry,
Shropshire,
England.

H.L. Frankel, F.R.C.P.,
Consultant Chairman, National
Spinal Injuries Centre,
Stoke Mandeville Hospital,
Aylesbury,
Buckinghamshire,
England.

SURGICAL TREATMENT OF SPINE INJURY

S.D. Gertzbein, M.D., F.R.C.S.(C)
Sunnybrook Medical Centre, University of Toronto, Toronto, Ontario Canada

ABSTRACT - The indications for spinal surgery are discussed in terms of spinal instability. The posterior, anterior and combined approaches are described and illustrated by clinical examples.

RÉSUMÉ - Les signes qu'une chirurgie rachidienne est nécessaire, sont analysés en fonction de l'instabilité de la colonne vertébrale. Les approches postérieure, antérieure et combinée sont décrites et illustrées au moyen d'exemples cliniques.

The goals of treatment of spinal injuries are: 1) to prevent further neurological damage; 2) to improve neurological function where possible; 3) to restore stability and alignment; and 4) to rehabilitate the patient to the maximum potential of his disability. This paper will concentrate on the concept of spinal instability and the means by which this can be achieved.

The spinal column consists of an anterior and posterior complex as well as a middle segment which includes portions of the anterior column and posterior complex. Spinal instability may be defined as the inability of the spine to resist physiological forces. Although imprecise, this definition allows one to place an injury along a spectrum ranging from minor to greater degrees of instability. Damage to the three parts of the spine can be assessed by: 1) the pattern of fracture; 2) the amount of displacement; and 3) the forces involved. In addition, late instability can be predicted from the extent of vertebral collapse and angular deformity. These parameters can be identified radiographically by means of specific radiologic studies including tomograms, flexion and extension views and the CT scan. In general, patients with anterior vertebral body collapse of greater than 30% or angular deformities in kyphosis greater than 30 degrees (or greater than ten degrees of scoliosis) are considered to have significant malalignment of the spine with potential for further deformity and delayed sequelae of pain and neurological complications.

Since the advent of Harrington rods, many of the previous objections to surgical intervention have been overcome. Spinal alignment and stability, as well as early ambulation can be achieved and earlier discharge to a rehabilitation centre is possible.

POSTERIOR APPROACH

Most unstable injuries with angular deformity and/or translational malalignment can be stabilized by means of rigid rods inserted two or three levels above and two levels below the fracture for maximum stabilization. The rods act as an internal splint which aligns the spine and provides three point fixation. Newer fixation devices, including segmental fixation have been used in the past three or four years to augment the stability. Contouring rods to the natural curves of the spine has resulted in a more physiological re-alignment.

For distraction injuries (Chance-type), compression systems have been used with excellent results. All instrumentation must be supplemented with bone graft to at least the level of the fracture. If the full length of the instrumentation is not fused, the rods must be removed at a second procedure one year later.

Deficiencies of posterior instrumentation using the Harrington system have been described. These relate to both technical inadequacies of surgery as well as particular fracture patterns, such as burst fractures with loss of vertebral height. The current device utilized by our Centre for the past three years, has proven to overcome some of the problems associated with the Harrington instrumentation.

ANTERIOR APPROACH

If anterior decompression of the spinal column is necessary to alleviate

pressure on the spinal cord, a bone block of corticocancellous bone is used to fill the defect. In some cases, anterior instrumentation can supplement the stability. Adequate alignment, however, is difficult using the anterior approach alone.

COMBINED APPROACH

For specific injuries, where major disruption has occurred both anteriorly and posteriorly, a combined anterior decompression, corticocancellous strut graft and second stage posterior instrumentation and spinal fusion has been found to be an effective method of obtaining rigidity, alignment and stability.

These techniques have allowed earlier mobilization and rehabilitation of patients with spinal injuries.

BIOMECHANICS OF SPINAL RECONSTRUCTION

Richard Whitehill, M.D.
Department of Orthopaedic Surgery, University of Virginia Medical Centre,
Charlottesville, Virginia

ABSTRACT - This paper gives an overview of the principles which are applicable to the design of surgical reconstruction of destabilized spines. Destabilized spines are those which are incapable of protecting the spinal cord. A variety of methods for treating this condition will be described.

RÉSUMÉ - Cette communication donne un aperçu général des principes applicables lorsqu'on envisage une intervention chirurgicale pour la reconstruction d'une colonne vertébrale déstabilisée. Dans les cas de déstabilisation, la colonne vertébrale est incapable de protéger la moelle épinière. On décrit un ensemble de méthodes pour traiter cette affection.

The purpose of this paper is to present principles which are applicable to the design of surgical reconstructions of destabilized spines. I would emphasize that the key word in the title is BIOMECHANICS as in biological mechanics. Hopefully, I will be presenting concepts which respect the biological environment into which they are to be placed every bit as much as the physical laws of mechanics to which they must conform. For example, it has always been particularly tempting to utilize the Kutschner intramedullary nailing system we so depend on in the treatment of femoral and tibial fractures to stabilize the injured spinal column. But can you imagine the neurological devastation that this would produce were it to actually be utilized?

For the most part, this presentation centers on patients who are suffering from spinal instability. White and Panjabi define these terms, that is - the unstable spinal column best. The destabilized spinal column is one which under physiological loading conditions is incapable of protecting the spinal cord within from either injury or irritation. They have developed a system of radiographic analysis which establishes radiographic criteria which the spine must satisfy in order to be defined as unstable. Specifically, on lateral flexion - extension x-rays the unstable spinal motion segment is one which angulates 11 degrees more or translates horizontally 3 1/2 mm. more than adjacent spinal segments.

One issue which must be addressed in any discussion of spinal reconstruction systems is, what is the natural history of the instability if treated, but without surgery? That is, how likely is a given injury pattern to develop ultimate mechanical stability if just given sufficient immobilization for sufficient time? We have identified two factors which, in general, determine whether or not the unstable spinal segment will go on to ultimate mechanical stability without surgical intervention. They are, in essence, whether the predominant mode of injury is ligamentous or bony.

For example, this is the lateral cervical x-ray of a young adult male who had suffered a predominantly ligamentous injury at C5-C6. This was confirmed by lateral tomography which showed no significant bony injury. The patient was treated at his own request non-operatively for three months in a halo-vest. A lateral flexion x-ray, taken after removal of the halo-vest, shows excessive kyphotic angulation which is still flexible at the old injury site. Thus, in this case,ultimate stability did not spontaneously result.

To the contrary, however, this is the initial lateral cervical x-ray also of a young adult male who suffered the predominantly bony injury shown. He was treated in halo traction for approximately four weeks followed by another eight weeks in a halo-vest. At this time, upon removal of the halo-vest, not only has the fracture been maintained in a well reduced position, but in addition, a solid bar of bridging bone is now noted anterior to the previously injured cervical vertebral bodies. Lateral flexion and extension x-rays confirm that in this specific case, ultimate stability had been spontaneously achieved.

The last two cases demonstrate another clinically applicable principle. The assumption is made that the spine is composed of two intimately interconnected columns (one anterior and one posterior). Thus, in order for spinal stability to be re-established, it is only necessary to re-establish stability in one of the two columns. Because of their interconnections, this will be sufficient to stabilize the entire segment(s) of injured spine. There are, of course, exceptions to this principle, but in general, they apply to the skeletally immature spine.

Thus, in general, when spinal instability is treated only orthotically, spontaneous stability occurs by virtue of bony and even to some degree, ligamentous healing in both columns. Sometimes

this results in a stable and also normally mobile spine, but at other times this results in spontaneous arthrodesis of the injured segments. When treated surgically, frequently, stability is created only in one column, but always by arthrodesis.

The problem with surgery is not that it is difficult to achieve solid arthrodesis, but that in some unstable cases it is difficult to maintain adequate alignment during the two to three months during which the fusion is healing. Therefore, internal fixation systems have been designed. Their purpose is to provide sufficiently rigid internal fixation of the unstable spinal segments during the healing phase so that a malaligned arthrodesis will be avoided.

In general, anterior internal fixation systems employing metallic devices have not been well accepted. This is because of the fear of such catastrophic complications as esophageal perforation and secondary infection and possibly, even death.

When such complications occur, they are usually secondary to inadequacies in the initial strength of the spine-appliance construct, leading to loosening and protrusion of the internal fixation apparatus anteriorly. For example, this is the lateral cervical x-ray of a patient with incomplete quadriplegia secondary to a flexion-axial loading fracture of C5 with resultant retropulsion of the posterior portion of the C5 vertebral body into the spinal canal. To decompress the spinal cord and to expedite neurological recovery, an excision of the vertebral body through an anterior surgical approach was performed. This created a void between the C4 and C6 vertebral bodies and in order to fill this defect a strut was fashioned from the patient's iliac crest. The strut was "fixed" into position with the barbed staple as shown. This, in fact, is a modified knee staple used for re-attachment of avulsed knee collateral ligaments and indeed, was inadequate for stabilizing the cervical spine in the case shown. In addition, no external orthotic support was applied to the patient's spine immediately postoperatively and thus, not surprisingly, within several days the staple had loosened and migrated anteriorly which necessitated its emergency removal.

Certainly, in anterior arthrodesis procedures, it is desirable to utilize an adequate anterior internal fixation system. It is conceivable that one can be developed which would provide sufficient immediate mechanical stability to allow a patient to enter into the early phases of his rehabilitation postoperatively with no external orthotic device. In fact, this may yet prove possible via a device such as a miniaturized compression plate. Although the literature now contains sporadic reports of the use of anterior plates, to my knowledge, these are not compression plates and the rigidity of fixation so created with their use is still in question. One of the major obstacles to the use of an anterior plate in addition to the potential for anterior migration is that fixation of the plate with screws which purchase both cortices of the vertebral body in a manner analogous to the way a compression plate is fixed to a long bone would be quite dangerous.

The posterior spine more readily lends itself to relatively rigid internal fixation systems. In the cervical spine, this is simply accomplished. Rogers initially described a posterior wiring system shown above. It consisted of passing a wire through the base of one posterior spinous process, looping it over top of the same process and then beneath the inferior spinous process to be included within the segment(s) to be fused. Based on what are now considered to be standard wiring techniques, useful for fractures in other areas, such as the olecranon, and popularized by the European AO group, we have modified the Rogers internal fixation scheme as follows: a simple cerclage is used. Two twists are placed, one on each side of the midline to assure that even tension is applied throughout. Using this system, it is possible to compress the posterior elements spanned by the fixation wire together. In cases in which the posterior bony elements are intact, this produces a construct which is quite stable not only in flexion, but also to some degree in axial rotation, lateral bending, and extension. The axial load bearing capacity of such a construct is less secure.

Some have chosen to add a layer of methyl-methacrylate cement over top of posterior fixation wire constructs in an effort to enhance their immediate stability. We have investigated such constructs in an in vitro and in vivo canine experimental model. A standard C4-C5 posterior preparation via the double twisted cerclage wire as shown above was utilized. Either autogenous bone grafts, methylmethacrylate cement, in standard volumes or no material was added after posterior element decortication. Animals were allowed to survive either one, two, or three months from the date of surgery. At sacrifice, the operated segments of the cervical spine were excised and tested mechanically. In addition, serial in vivo x-rays and pre- and post-mechanical failure specimen x-rays were obtained on all constructs. Finally, following mechanical testing, horizontal sections through the center of all constructs were microtomed and stained with Hematoxylin and Eosin for microscopic examination.

Immediately postoperatively, based on mechanical analysis of in vitro preparation analogous to those implanted in vivo the constructs utilizing the methylmethacrylate cement were superior in respect to stiffness, but, in fact, not significantly stronger nor did they absorb greater energy than the bone graft constructs of the controls. By the end of the first postoperative month the methylmethacrylate

constructs had even lost their advantage in respect to stiffness. In addition, histologically, a layer of fibrous tissue had insinuated itself between the methylmethacrylate cement mass and underlying posterior element bone at this time. By the end of the second postoperative month, the majority of the methylmethacrylate constructs demonstrated wire fracture and cement loosening. Mechanically, they were now inferior to the bone graft constructs. By the end of the third postoperative month, not only were multiple wire fractures evident in the methylmethacrylate constructs, but in addition, obvious loosening of the cement from the underlying posterior elements was noted radiographically. Again, the methylmethacrylate constructs were mechanically inferior to the bone graft constructs.

Based on these laboratory findings, therefore, we are very reluctant to utilize combinations of methylmethacrylate cement and cerclage wires, especially in patients with traumatically destabilized cervical spines. We believe that there are two basic defects inherent in such a construct. First the cement is loaded in tension which as in other portions of the body have been shown to inevitably lead to cement bone interface loosening. Second, the cement cannot possibly completely encase the entire cerclage wire especially in that area where the wire passes through the very small bony drill hole. Thus, the junction of the covered wire with the uncovered wire is an area of stress concentration which inevitably leads to wire failure.

Most recently, Carol, Ducker, and Pentacost have developed an articulated rod and ball joint system for posterior cervical internal fixation use. The device is fixed to the posterior elements via footplates which slide into facet joints. In addition, the exposed portion of the footplate lying over top of the facet joint is fixed by a cortical bone screw which gains purchase in the more posteriorly positioned inferior articular facet. It seems that this device has the capacity to be used either in compression or distraction. In the latter capacity, it could be quite useful as an internal splint holding a comminuted vertebral body (burst fracture) in a reduced position, functionally decompressing the spinal cord by returning the deminsions of the spinal canal back to a normal state. If it was felt necessary to directly exercise a comminuted vertebral body which had retropulsed into the spinal canal to decompress the spinal cord, then the device could still be used posteriorly, to maintain spinal alignment while purely cancellous bone graft was solidifying anteriorly. This would eliminate, at least theoretically, a need for the somewhat time consuming fashioning of an anterior strut and in addition, complications to anterior internal fixation of such a strut. We are currently in the process of studying this device in a canine in vivo experimental model.

Finally in closing, with a view to the future, I would like to point out how very primitive, in a sophisticated way, our approach to spinal stabilization in general has been over the years. That is, nearly all of our surgical reconstruction procedures take the final common pathway of arthrodesis. If an athlete presents with an injured knee, we do not rush to a knee fusion. If a patient presents with a painfully arthritic hip, we do not routinely initiate treatment with a hip fusion. Admittedly, the loss of mobility is not all that significant when a mid cervical fusion is performed in a limited fashion. However, every solid cervical fusion we achieve can also be thought of as an iatrogenic Klippel-Feil syndrome. In such cases, excessive stress must be placed on adjacent normal spinal segments. We have noted and documented excessive motion at these adjacent levels. We do not yet know the natural history of this increased flexibility, but it is certainly possible that it will be clinical instability. Thus, possibly in the future, we may need to perfect spinal arthroplasty procedures as an alternative to our current arthrodesis procedures.

STUDIES OF EXTERNAL STABILIZATION OF THE CERVICAL SPINE

P.S. Walker, Ph.D., D. Lamser, S. Gordon, A. Farnerov, Ph.D., J. Dietz
Veterans Administration Medical Centre, West Roxbury, MA 02132 and Brigham and Women's Hospital, Boston, MA; affiliates of Harvard Medical School and Massachusetts Institute of Technology.

ABSTRACT - A study of Koch and Nickel (1978) determined the distraction force in the halo-vest during different activities. The present study determined the force changes in the anterior-posterior and medial-lateral directions, also during different activities. Strain gauges were clipped on to the bars while an on-line computer system was used to compute the forces. Anterior-posterior forces were comparable to vertical ones. These forces, and the changes during a particular activity were caused by gravity forces of the head in activities involving a change in attitude; and vest distortion from changes in body shape, or direct pushing from the lower abdomen, the arms and shoulders, or supporting surfaces. Activities producing the highest force changes included bending forwards from a seated position, and reaching over sideways while lying. Medial-lateral forces were small in comparison. Implications were that pin- skull forces were multidirectional, and that certain improvements in design could be effected by accounting for the factors which caused high forces and consequently to cervical motion.

INTRODUCTION

The most frequently used method of treating cervical fractures or dislocations where the neurological damage is not severe, is an initial period of traction followed by application of the halo-vest apparatus for two to four months (Cooper, 1979). The original halo-plaster body cast, was described by Perry and Nickel in 1959 and reviewed later (Nickel, 1968; Perry, 1972). The design criteria were precise positional control in three planes, adjustable longitudinal traction, rigid stabilization, simple application, freedom from complications and minimum patient discomfort. There are certain inherent problems with the halo-vest (Cooper, 1979) such as infections or loosening around the pins, requiring removal and change of location, and ulceration under the plastic vest.

Since the primary purpose of the halo-vest apparatus is to stabilize the cervical spine, a number of studies have addressed this point. White (1975) defined clinical stability as the ability of the spine to limit its patterns of displacement under physiologic loads so as not to damage or irritate the spinal cord or the nerve roots. Three studies (Hartman, 1976; Johnson, 1977; and Fisher, 1977) gave broadly similar results. In flexion-extension, soft collars allowed 74-90 percent of normal unrestricted motion, plastic collars 25-35 percent, and the four-posters, two posters, and the somi 10-28 percent. The halo-vest allowed a maximum of only 4 percent in all directions. However, striking new data on cervical spine motion when patients carried out different activities, showed that the previous studies gave underestimates and a false sense of security in actions such as being moved from the supine to the upright position (Koch and Nickel, 1978).

The impetus for our study was to examine whether cervical motion could be further restricted by a new type of non-invasive orthosis. This is feasible since Fisher (1978) showed how accuracy of fit could restrict motion to less than 10 percent in certain orthoses. Other successful results with non-invasive devices have been reported (Wilson, 1978; Abrahams and Shrosbree, 1979).

Our study attempted to expand upon that of Koch and Nickel by measuring forces in different directions, on halo-vests of different design. This data could then be used to specify motion planes where maximum stiffness was required.

2. MATERIALS AND METHODS

The forces between the halo and the vest were represented by three forces and three moments at each of the connections between the upright bars and the halo (Fig. 1). Inductive strain transducers (Hottinger-Baldwin type D1) were attached to specific locations on the metal connecting rods using elastic bands, with the halo-vest in situ on a patient (Fig. 2). The transducers had a guage length of 20 mm and a sensitivity of 1 micro-strain. A 5 kHz carrier frequency was provided (Celesco Carrier-Demodular Units) and the output signal amplified and dis-played on a chart recorder (Gould). For computation purposes, the amplified signals were fed to a mini-computer (Apple Plus 2) through an 8-bit a-d converter (Mountain Hardware). Four of the transducers were used at one time, positioned on the bars in different sequences from which various of the forces and moments could be calculated.

Referring to Figures 1 & 2, two transducers are placed in the sagittal plane on opposite sides of a vertical bar.

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For Σ_A and Σ_p = strain at anterior and posterior of the bar

L, A, d, & I = length, area, diameter and 2nd moment of area of bar

E = modules of elasticity

$$\Sigma_A = \frac{F_Y}{AE} - \frac{F_x.1/2L.1/2d}{EI} + \frac{M_z.1/2d}{EI}$$

$$\Sigma_p = \frac{F_Y}{AE} + \frac{F_x.1/2L.1/2d}{EI} - \frac{M_z.1/2d}{EI}$$

$$\therefore (\Sigma_A+\Sigma_p) = \frac{2F_Y}{AE}$$

$$\text{and } (\Sigma_p-\Sigma_A) = \frac{2.F_x.1/2L.1/2d}{EI} - \frac{2M_z.1/2d}{EI}$$

$$\therefore F_Y = 1/2AE(\Sigma_A+\Sigma_p)$$

$$F_x = \frac{2EI(\Sigma_p - \Sigma_A)}{dL} + \frac{2M_z}{L}$$

In the latter expression, if the moment about the transverse axis through the bar-halo connections (M_z) is assumed to be small, then F_x can be solved. However, the axial strains produced by F_y are small, especially compared with the bending strains, and a better way of solving for F_y was to place the transducers on the horizontal bars, for which similar equations were written. Further equations were written for the overhead type of halo-vest (e.g. the Ace Conventional Halo with jacket or body-cast).

A sequence of activities was then carried out by the volunteer. The stain readings from the four transducers was continuously recorded during the two to four seconds of the activity. The computer program determined the forces for this time period, and specified the maximum forces and when they occurred. The data was displayed on the video within a few seconds to enable rechecking if necessary. The zero force was taken to be when the volunteer was initially sitting, standing upright, or lying down, depending on the subsequent activity.

The tests were carried out on four normal male volunteers ages 25-40, using a standard Ace low profile Halo Vest. In place of skull pins, rubber pads were tightened against the side of the head. Five patients were studied, with a variety of types of halo-vest, and whose medical details are shown in Table 1.

A prototype device was constructed to test the theory of obtaining adequate stabilization without skull pins. The design criteria were: adequate stabilization (especially in the a-p plane), non-invasive headpiece, a-p & flex-ext headpiece adjustment, comfortable, allows radiology, low profile, less than 75% weight of current halos, fit to various body shapes, allows arm movements without hindrance. The device was fitted to 3 normal subjects. Maximum flexion-extension and medial-lateral forces were applied and radiographs taken to determine motion between segments.

3. RESULTS

The majority of the results for the vertical force component F_y were obtained from the normal volunteers. This force ranged from 0.5 to 46 Newtons, with an average of 14.7 Newtons, for all of the activities. This was on one side of the halo-vest only, so assuming symmetry for most of the activities the average total F_y was 29.4 Newtons. The highest values were obtained in going from standing to lying or vice versa, and in reaching with the arms across the chest while lying. The one patient from whom F_y data was obtained gave values on one side of between 43 and 93 Newtons for activities while seated, similar to data of Koch and Nickel (1978).

All of the side-to-side F_z forces were obtained for normals. Actively pushing the halo side-to-side gave a range from 8.5 to 22.7 Newtons, limited by pain, while lying and then reaching with the arms across the chest gave close to the same values. Forces in other activities were much lower.

The values of front-to-back horizontal force, covered a wide range. Most of the average values for one side of the halo-vest, lay close to 25 Newtons, and there were no apparent differences in the results between patients and normals (Fig. 3). The one exception was that one patient (TB) showed unusually high values, being at the high end of the range in each case. This individual was well-built and put considerable effort into each activity. Bending towards the floor from seated produced force changes that would be expected from the weight of the head. On the other hand, pushing up from a seat did not produce especially high F_x forces. Turning left to right did however produce high forces, in opposite directions on each side of the halo. When starting from standing, reaching upwards, or bending forwards often produced high forces due to both gravity forces and to distorting the fit of the vest on the body. For similar reasons, getting onto a bed or lying on the floor often produced higher forces than average, while the distortion effect of the vest on the body was especially noticeable in reaching with the arms across the chest from a lying position. The sports exercises produced relatively low forces probably because the gravity effects were small as was the distortion of the jacket.

With the prototype device, the intersegmental motions are shown in Figure 4 and are tabulated below:

	Anterior-Posterior		Med-Lat
	SG	PW	TC
skull-C1	9°	7°	
C1-C2	6°	5°	
C2-C3	2°	1°	
C3-C7	0°	0°	
C4-C5			5°
C5-C6			5°
C6-C7			4°

It can be seen that the upper segments were the most difficult to stabilize.

4. DISCUSSION

To assess the resultant forces of the pins in the skull, and forces which are likely to cause cervical movement, the force components between the halo and the vest along three axes need to be known. Our method provided for this and also allowed the convenience of being able to place the measuring transducers on any type of device and at any stage of the treatment. In order to compute the values of F_x, F_y, and F_z, the assumption had to be made that the moments at the vertical rod-halo junction were small. Examination of the structure and of the degrees of freedom of the head relative to the thorax suggests that this assumption is reasonable. This was further supported by the results from the head forces in four different directions. Notably, the force was the same no matter what the level of applying the force.

Study of the numerous stain tracings revealed several points. Gravity forces were the major factor in many activities where the body and head changed its orientation. Actively pushing or distorting the vest, also resulted in high strains and high halo forces. On the other hand, inertial activities, such a jogging on the spot or curling, even if high muscular effort was needed, did not produce high forces.

The results for the vertical force component were consistent with those of Koch and Nickel (1978), in the magnitude of the changes occurring during different activities. The medial-lateral forces were small in comparison with the forces in the other directions, except for reaching with an arm across the chest while lying. The changes in the forces in the anterior-posterior direction were similar in magnitude to those in the vertical direction, due to the same principal factors mentioned above, gravity forces and vest distortion forces.

There are several implications to our results. The forces of the pins in the skull will be primarily shearing forces, acting in multiple directions. Because of this, it is expected that the pins will enlarge the hole in a crater-like manner, suggesting that pins which broaden out radidly from a point would tighten more effectively than those with a slower taper (Perry, 1972). The patient could assist with reducing pin forces by restricting or modifying activities which caused the highest force changes. For example, reducing the amount of general movement while lying or seated, as well as elevations of the arms, would help to achieve this. Avoiding looking upwards, bending forwards, and turning sideways too rapidly, would reduce the gravity effects of the anterior-posterior shearing forces.

Finally, there are a number of possibilities for design improvement, a subject of current work in our laboratory. The vest itself is the weak link in terms of allowing movements and distortions to occur. Stiffening the vest and supporting it against more rigid parts of the torso and avoiding support on the moveable clavicle, appears to assist. Higher stiffness to bending in the sagittal plane than the frontal plane is indicated from the force data. Supporting the posterior surfaces of the head and neck restrains one degree of freedom of the cervical spine and should minimize the effects of bending and shear forces on spine movement. Whether a non-invasive headpiece, combined with an improved vest arrangement, would equal the cervical stability provided by the current halo-vests, is a subject of continued investigation.

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FIGURE LEGENDS

Figure 1: The force and moment system referred to x-y-z coordinates at the vertical rod-halo connections.
Figure 2: A volunteer patient with transducers attached to vertical rods.
Figure 3: The forces in the x-direction (anterior-posterior) for all different activities. The lowest, average and highest values are shown. Note that the forces are for one side of the halo. For symmetrical activities, the total force will be about double.
Figure 4: Intersegment movements at extremes of flexion & extension, for a normal subject with a prototype non-invasive device.

TABLE 1: DETAILS OF THE PATIENTS TESTED

Name	Age	Injury	Type of Device	Time in Device Before Test
GH	49	Fx odontoid	Ace Mk II Halo-Vest	8 wks
KC	28	C6-C7	Ace Mk II Halo-Vest	4 wks
TB	22	C6-C7	Overhead alum. Halo-Vest	6 wks
RZ	18	Fx C2	Alum. Mk. II Halo-Body Cast	3 wks
PM	23	C6-C7	Ace Mk II Halo-Vest	6 wks

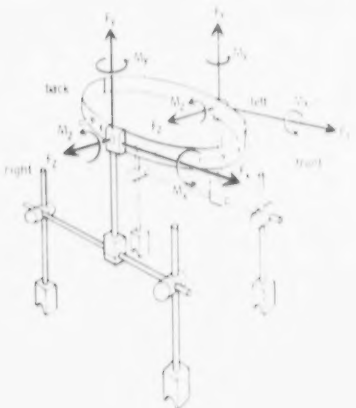

FIG. 1

FIG. 2

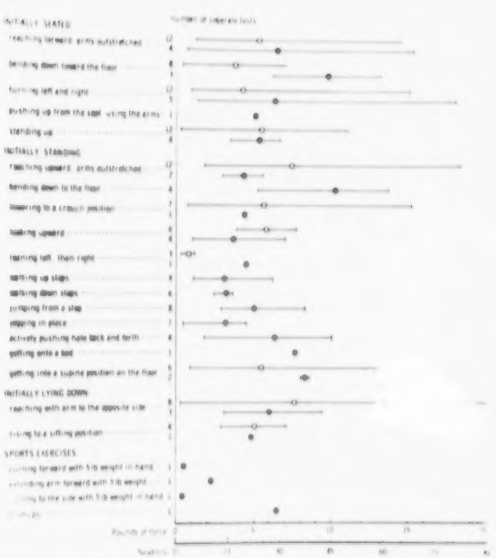

FIG. 3

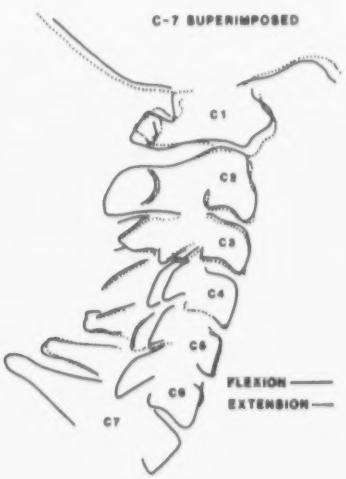

FIG. 4

EVOKED POTENTIAL MONITORING OF SPINAL CORD FUNCTION: TECHNIQUES FOR INTRAOPERATIVE RECORDING

Marc R. Nuwer, M.D., Ph.D.
University of California, Los Angeles, CA 90024, U.S.A.

ABSTRACT - Intraoperative monitoring of spinal cord function can identify acute cord impairment in time for surgical intervention to remedy the problem before permenent damage is done. Several techniques are available for recording from the spinal cord or the scalp.

RÉSUMÉ - Le contrôle peropératoire de la fonction de la fonction de la moelle épinière peut déceler une lésion importante de cette dernière à temps pour permettre une intervention chirurgicale visant à corriger la situation avant qu'il n'y ait dommage permanent. Il existe plusieurs techniques pour le contrôle de la moelle épinière ou du cuir chevelu.

Intraoperative monitoring of somatosensory evoked potentials (EP) can improve the margin of safety during surgical procedures around the spine. Over the past decade, several different techniques have been developed for the measurement of intraoperative EPs. Generally the EPs can be collected continuously without asking the surgeon to pause during the operation. This can provide a surgeon with sufficient warning about spinal cord compression, ischemia or other impairment so that the cause of the impairment can be rectified before permanent damage has been done.

Paraplegia or paraparesis is one of the complications seen after surgery around the spinal cord. The degree of risk varies with the type of pre-existing pathology and with the surgical procedure. Intraoperative evoked potentials are appropriate in any setting where real risk of these complications exists, and where the surgeon would be able to intervene and potentially correct some of the causes of acute impairment.

Scoliosis is one of the most common operations for which intraoperative somatosensory EPs are used for spinal cord monitoring. The risk of lower extremity neurologic impairment is estimated to be at least 1.7% in adults (8). The major pathophysiological mechanism is probably ischemia due to cord compression. A variety of animal models have been used to study spinal cord ischemia and they suggest that EP monitoring is indeed an effective tool for early detection of spinal cord compression. Acute postoperative paraplegia or paraparesis and associated cord pathology only occur when the EP has been significantly changed. The parallel between EP and motor impairment occurs despite the fact that a major part of the EP transmission is up the posterior columns. Once the spinal cord has been significantly impaired and the EPs have been altered or abolished, permanent motor impairment can still be avoided if the ischemia is reversed promptly (e.g., within 15 minutes) (2, 9).

Observations in human subjects parallel this animal research. No cases have been reported where neurologic impairment occurred despite unchanging normal EPs. Systemic problems such as hypoxia or hypotension can also be detected by the EPs, and are occasionally the earliest sign of such a problem (4). A variety of EP changes are seen due to drugs, the most striking of which is the abolition of cortical EPs during anesthesia with isoflurane or other halogenated inhalation agents.

The earliest clinical technique for intraoperative somatosensory EPs was with electrodes placed into the spinal epidural space for both stimulating and recording (15). Similar techniques have evolved using epidural electrodes only for recording, and instead stimulating at a peripheral nerve such as the common peroneal or posterior tibial (6). Other similar recording electrode sites include placements in the interspinous ligaments or into the caudal equina (5, 7).

An entirely different approach is the recording of evoked potentials over the scalp instead of over the spinal cord (1, 3, 10, 13, 14). Using these techniques, several very basic principles of spinal EP monitoring have been described: Some moderate variability occurs without any clinical significance. However, if more than 50% amplitude attenuation occurs, occasional postoperative neurologic impairment may follow. If the EP changes or disappears transiently but quickly returns to its baseline, postoperative neurologic impairment is rare. The total permanent abolition of EPs is often but not always followed by postoperative neurologic sequalae.

No single set of technical parameters have been established as the best overall technique for recording these EPs. Three somewhat different sets of parameters are in general use, each with their own advantages and disadvantages (see Table

1). The first technique uses a principal recording electrode placed just behind the scalp vertex in the midline, and another referential electrode placed on the forehead, neck, ear or shoulder. The filters on the recording amplifiers are set to 0.3 or 1 Hz for the low linear frequency filter, and 250 to 1000 Hz for the high frequency filter. The second type of technique uses pairs of scalp electrodes placed closely together just behind the scalp vertex. In this technique the filters are set to 30 Hz and 3 kHz. The final general method currently in use in North America involves recording electrodes placed around the spinal cord itself on or in various structures or spaces. In this technique filters are set at 30 Hz and 3 kHz. In each of these techniques the peripheral nervous system is stimulated, either at the peroneal nerve as it passes around the head of the fibula or at the posterior tibial nerve as it passes behind the medial malleolus. The nerves are stimulated with brief (e.g., 50 to 500 microsecond) square wave pulses of sufficient voltage or current to cause small movements of the extremity in an awake person. For the scalp techniques, the optimal rate of stimulation is at about 5 per second. This seems to be the best trade-off between speed of producing EPs and attenuation that occurs at fast rates of stimulation (11).

After investigation of various effects of filter settings, scalp electrode placements, rates of stimulation, and other parameters, the scalp recording restricted filter bipolar technique has been adopted at my institution. The restricted filters do appear to reduce the ordinary, background variability of the EPs (see Figure 1). This allows the recording of reproducible EPs from the scalp. However, in some settings the scalp methods are not appropriate. We have had difficulty recording these scalp evoked potentials reliably in older patients, or in patients in whom halogenated anesthetic agents are needed (e.g., because of respiratory disorders). Therefore, the optimal way to monitor intraoperative somatosensory EPs for spinal cord monitoring may involve a combination of several of the existing techniques. For example, scalp techniques might be best used during the opening and closing phases of an operation, and epidural recording techniques might be most sensitive during the middle part of the operation at which point the epidural leads can be used to produce very low noise, very reproducible EPs. There are several settings in which the epidural leads are not appropriate such as cases in which the spinal cord is not being exposed (e.g., in operations in which the aorta is being cross-clamped through an anterior chest or abdominal approach, or cases in which the sciatic nerve is

TABLE I

COMPARISON OF RECORDING METHODS FOR INTRAOPERATIVE EVOKED POTENTIALS

	SCALP: OPEN FILTERS, REFERENTIAL	SCALP: RESTRICTED FILTERS, BIPOLAR	SPINAL: EPIDURAL OR AT LIGAMENTS
Typical Electrode Placement	vertex to ears	vertex pair	epidural to muscle
Low Filters	0.3 to 1 Hz	30 Hz	30 Hz
High Filters	250 to 1000 Hz	3000 Hz	3000 Hz
Minimum Time to Produce Each EP	1 minute	1 minute	10 seconds
Noise & Variability	moderate	low	low
With Forane 0.5%	gone	usually gone	perserved
Can Also Monitor Caudal to Surgical Site	no	no	yes
Begin Monitoring	at induction	at induction	after exposing epidural space
Discontinue Monitoring	after awakening	after awakening	upon closing
Wires	at scalp	at scalp	in surgical field
Risk	none	none	low

in jeopardy during hip replacement surgery). In those cases only the scalp methods seem practical.

Another setting for use of serial evoked potential studies is in the ICU. Patients in an ICU who have serious risk of spinal cord ischemia or compression may benefit by repeated or continuous somatosensory EP monitoring. Investigations of the proper parameters for these patients have again suggested that electrodes should be placed near the mid-sagittal plane (12). Optimal filter settings for ICU patients have not yet been established.

We have seen attenuation of intraoperative EPs on several occasions, identifying patients who have indeed had postoperative neurologic sequalae. In other cases the EPs have transiently disappeared or become substantially attenuated, and the surgeon was able to alter the course of the operation in such a way to reduce the risk of postoperative problems for the patient. In some cases this has involved temporary removal of a Harrington rod. Figure 2 shows EPs recorded from a patient in whom a spinal cord arterial venous malformation was being clipped. Further clipping of feeder arteries was discontinued after an episode of transient loss of the EPs. In such a setting one cannot clearly say that the patient would have been left with neurologic sequalae if the surgeon had proceeded to clip the remainder of the feeding vessels. The actual decision about an intervention to be taken upon EP change is a complicated question that must be answered in an individual patient setting.

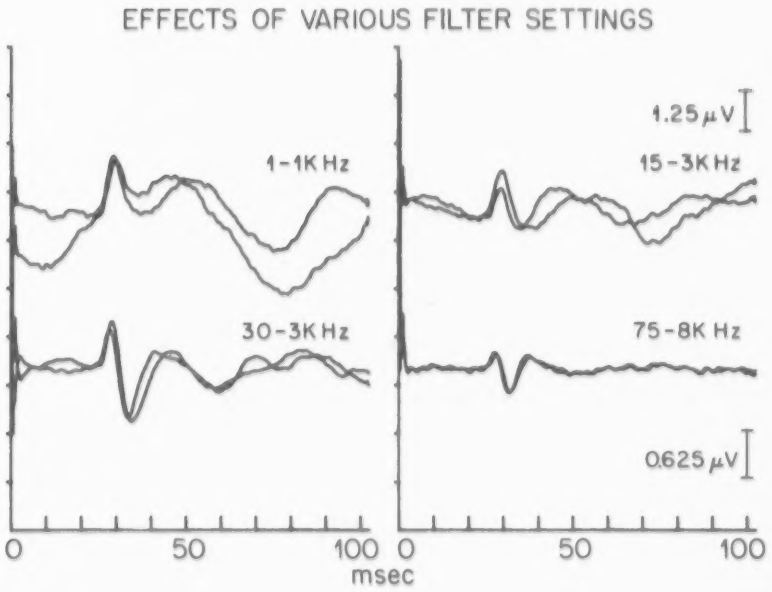

Figure 1.

The ordinary variability of EPs can be reduced by restricting the filters on the amplifiers. Four examples shown are from the same patient, same electrodes. Two separate repetitions were recorded using four different sets of filters. Moderate variability occurs with 1 Hz and 15 Hz low filters. With a 30 Hz filter the EPs are much more reproducible (note peak to peak amplitudes). At a 75 Hz filter setting, the two separate repetitions are almost superimposable. The peroneal nerve stimulus was delivered at time zero. (Reproduced with permission, Clin. Orthop., ref. 10).

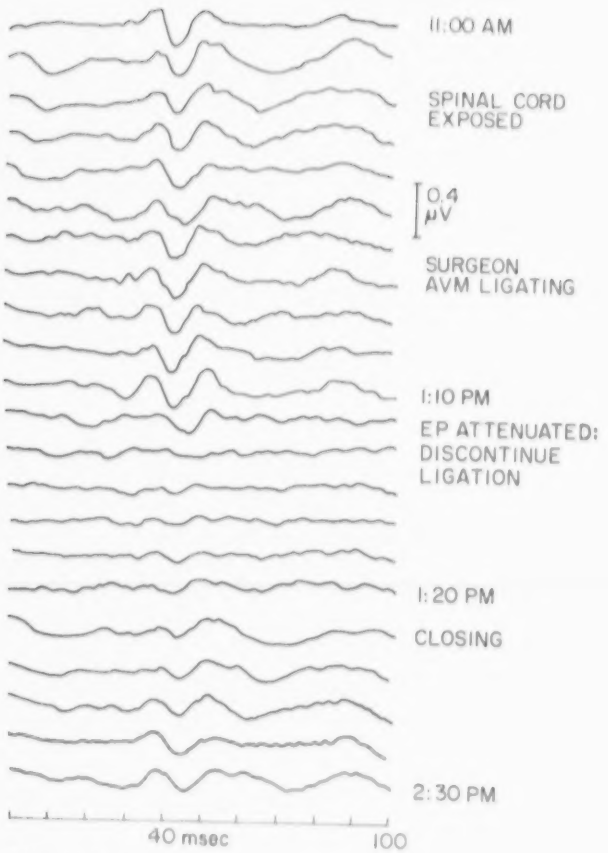

Figure 2.

Disappearance of EPs in this patient warned the surgeon against further ligation of a thoracic cord arteriovenous malformation (AVM). When the EP disappeared most the proposed ligation had been accomplished; further intervention was stopped. EPs returned to normal amplitudes in about one hour, although latencies remained more delayed. Stimulation was to one peroneal nerve and recordings were at the scalp. The patient awoke without any new neurologic impairment. (Reproduced with permission, Electroenceph. and Clin. Neurophysiol., ref. 11.)

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EXPERIMENTAL SPINAL CORD INJURY STUDIES

J.L. Osterholm, M.D.*, J.L. Alderman, Ph.D., B. D'Amore, B.S., H. Williams, M.T.
*Thomas Jefferson University, Co-Director Delaware Valley Spinal Cord Injury Centre, Philadelphia, PA, U.S.A. 19107

ABSTRACT: This paper describes the experimental techniques used in spinal cord injury (SCI) studies and the significance of the results. Factors influencing spinal cord injury will be discussed including global and regional ischemia, nerve terminal patterns and the effects of pharmacologic intervention in preserving cord function.

RÉSUMÉ - Cette communication décrit les techniques expérimentales utilisées pour l'étude des lésions de la moelle épinière ainsi que l'importance des résultats obtenus. On discutera des facteurs qui influent sur les lésions de la moelle épinière, y compris les ischémies globales et régionales, la configuration des terminaisons nerveuses et les effets de l'intervention pharmacologique sur la préservation des fonctions de la moelle épinière.

This laboratory has expended considerable effort investigating spinal cord methodologies. After careful appraisal of the various known methods, and those which could realistically be developed, we selected the weight dropping technique. A compelling reason for our choice was that, at least on a theoretical basis, the method should be relatively free of obvious errors simple to accomplish and therefore provide the best reproducibility. There was, however, unacceptable variability in our early spinal impact studies. By redefining a standard laminectomy opening, rigidly fixing the animal and guide tube, restructuring the impactor we gradually achieved injury reproducibility. The errors found, are in the majority due to features retarding full injury force. A technically inadequate injury is therefore less severe than intended. The converse almost never occurs. Fortunately, there are now monitoring methods to compliment the operators' interpretation of wounding adequacy. A severe injury causes an immediate rise of systemic blood pressure. The persistence of somato-sensory evoked potentials after severe injury provide evidence that the wound was unsatisfactory. Certain pathophysiological animal responses appear after severe wounding and these are also taken as confirmatory evidence about the injury. These summated features compliment and immediately document the system both mechanically and biologically.

After the model was satisfactorily documented, we did sequential histological studies on the injured tissue. In agreement with the findings of other laboratories, traumatic lesions are composed of microregional hemorrhages and separate fields of necrosis. The term traumatic hemorrhagic necrosis (THN) was coined to describe the characteristic injury lesions. We developed a lesion quantitation system and a definitive progression of the lesion with time was found. When the lesion volume was plotted semi-logarithmically against time, a straight line results with different slopes for grey and white matter. Using these basic THN curves it is possible to predict a lesion size at any experimental time within ± 10% accuracy. The use of histopathological lesion quantitation in acute interactive studies is invaluable. Statistical analysis on pharmacological treated materials can detect a drug induced lesion variance. From these computations several drugs have now been identified as worthy of further study.

Based upon the well characterized lesion progression over twenty-four hours, and the fact that blunt trauma neither lacerated nor mechanically disrupted the tissues, it was obvious that regional cellular and/or vascular events continue to cause tissue destruction long after the traumatic mechanical event had passed.

Regional Spinal Cord Blood Flow

It is now well accepted that regional spinal cord blood flow falls in the local grey matter after impact injury. These findings have led to the hypothesis that a local reduction in microcirculatory flow may contribute significantly to the loss of structure and function that follow spinal cord injury. But, the actual extent to which flow reduction influences spinal cord injury outcome is as yet unclear. The critical levels of blood flow necessary to support normal spinal cord function have not been rigidly defined. Both mechanical stimulation of nervous tissues and the associated severe ischemia are clearly involved to some degree in spinal cord injury. Before rational therapeutic attempts to reverse the pathophysiologic events that ultimately lead to paralysis, it is necessary to differentiate the relative influence of these two factors.

White matter blood flow changes are less clearly understood. White matter tracts represent a common pathway for sensory and motor impulses to be distributed to segments of the nervous system above and below the injury; thus lesions in the white matter produce the greatest neurologic deficit. Although classically grey matter was regarded more sensitive to ischemia than white,

recent evidence indicates white matter may be damaged (and grey matter unaffected) by mild prolonged ischemia (1). The quantitative relationship between loss of function and ischemia in the white matter has not been explored in the injured cord.

The normal anatomical distribution of the spinal vasculature has been well described by Turnbull (2) and DiChiro (3). In the thoracic region branches from a number of intercostal arteries enter the spinal canal to form numerous posterior and a lesser number of anterior radicular arteries. The radicular vessels feed a coronal pial plexus which eventually forms one continuous anterior spine artery, and two, often discontinuous, posterior spinal arteries. Parenchymal branches from the anterior spinal artery penetrate the pia to supply the bulk of the central portion of the spinal cord. The peripheral cord is nourished by the pial plexus; this is fed by the posterior system and anatomic branches from the anterior spinal artery. The intermediate cord is supplied by both arterial systems. As can be seen from a microangeographic preparation, the grey matter is much more densely supplied by vessels than is white.

Early experiments by Killen and Atkins demonstrated that experimental intercostal occlusion regularly resulted in paraplegia when distal intercostal pressures fell below a critical perfusion pressure of 30 torr. Of course, flow depends upon both the perfusion pressure and the resistance of the vascular bed. When either factor is sufficiently disturbd, the cord circulation will be embarrassed. These factors are well known clinically, e.g., aortic occlusion during surgery for dissecting aneurysms.

The first quantitative spinal cord blood flow studies were carried out by Landau (6) in 1955. Utilizing trifluoroiodomethalene autoradiography he found blood flow to be 14.0 ml/100 gms tissue/min. in the white matter and 63.0 ml/100 gms tissue/min. in the grey matter of the normal feline spinal cord. Marcus (23) found a similar disparity in white and grey matter blood flows by utilizing radioactive microspheres and mechanically separating the two tissues. The microsphere technique was unable to depict small local variations within the grey and white compartments.

Ducker and Perot (7) using a ^{133}Xe washout technique found average spinal cord blood flow (encompassing both white and grey matter) to be 15.2 ml/100 gms/min. for the normal dog. They also found flow to be responsive to changes in arterial pCO_2 and to be independent of perfusing pressures over a fairly wide range. Using the hydrogen clearance technique Kobrine (5,8) and Griffith (9) corroborated these values. The lower limit of autoregulation of spinal cord blood flow was found to be 50 torr. Analysis of representative data (8) revealed white matter flow was 17.5 ml/100 gms/min. Flow from the center of the cord was 14.0 ml/100 gms/min. This low value presumably represents grey matter and is unexpected in view of the grey/white flow values from other portions of the nervous system, vessel density, and the work of Landau (6) and Marcus (23). The abnormally low grey matter flow values with the hydrogen clearance technique likely appear because of dilution by a prominent white matter component (10,11). The most definitive method presently available for the determination of local blood flow is the autoradiographic technique based on the uptake of a chemically inert diffusible radioactive tracer into the tissue studied (12,13).

Effect of Injury on Spinal Cord Blood Flow

Assenmacher and Ducker (16) observed the pial microcirculation after severe spinal cord injury. They found parenchymal hemorrhages in 30% of the acute lesions immediately following wounding. All specimens became hemorrhagic in the subacute injury phase. Immediate vascular stasis was observed in only 5% of acute lesions. This became progressively more evident and increased to 30% at 30 minutes, 65% at 8 hours and 100% at 5 days.

Fairholm and Turnbull (17) and Fried and Goodkin (18) in a series of experiments utilizing regional microangiography at the injured segment demonstrated non-filling of central grey vessels. The resulting necrotizing process produced an amorphous avascular area surrounded by an area of more profuse vascularity. The latter phenomena suggests the development of a region of "luxury perfusions" such as described for cerebrovascular occlusions. Using a particulate fluorescent marker Dohrmann (19) has confirmed these observations.

We have oberved another major vascular response in acute microangiographic preparation. Large lakes of contrast are seen which represent sizeable microregional hemorrhages developing in much of the traumatized grey. The cord is circumferentially restricted by the pia, and may not easily accommodate a mass of this size. If the increased mass is of sufficient magnitude, local tissue pressure may rise producing slowing of the local microvascular circulation.

A number of quantitative spinal cord blood flow studies have been reported following injury (11,20-22,24-28). Utilizing a variety of methods to produce the injury, and a number of techniques to measure flow it is universally accepted that severe trauma reduces a profound fall in grey matter flow. Tator (11) demonstrated that the flow reductions were force related. Bingham (20,21) found flow reduction to be greater after 400 than 300 gm-cm injuries as well. The effect on spinal cord function of flow reductions of this order of magnitude have not been adequately demonstrated.

Sandler and Tator (26) utilizing the autoradiographic technique found that severe compression of the cord for three hours reduced white matter flow to extremely low levels for 24 hours after trauma. In contrast with the above mentioned reports, a mild flow reduction or no reduction at all during the first few minutes post impact injury followed by a hyperemic response ("luxury

perfusion") has been reported by Kobrine (24), Bingham (20), and Griffiths (25). Using the same technique Senter and Venes (28), however, found flow in the lateral funiculus to fall to ischemic levels following impact injury. Flow was maintained for a one hour period following trauma. In contrast Rivlin and Tator (27) found using the autoradiographic technique that flow fell rapidly within 15 minutes following a compression injury to the cord.

A closer examination of the above mentioned reports will reveal that the discrepancies are not as significant as they appear at first glance. The differences in the methodology of injury production are obvious: Kobrine (24), while Sandler and Tator (26) compressed the cord by inflating a cuff. In the studies utilizing impaction, the mechanical forces used to impact injury the cord varied from 300 gm-cm to 600 gm-cm. In this respect it is important to note that while white matter hyperemia was reported after 300 gm-cm injuries, the same authors described profound ischemia when the impacting force was 400 gm-cm. Also, Sandler (26) in a separate experiment demonstrated that following threshold injury in which 50% of animals were rendered paraplegic, white matter flow was only transiently reduced and subsequently rose to normal levels at 6 hours, and was increased significantly at 24 hours. With a more severe injury producing paraplegia consistently, however, a profound and persistent ischemia was noted.

Other study methods support the thesis that microcirculatory failure plays a significant role in the genesis of spinal injury. During the course of direct measurements in acute cord trauma Kelly (29) found dramatic depressions of local tissue oxygen in the white matter of the dorsal columns. One hour after experimental injury oxygen tensions became depressed far below normal tissue requirements, and once hypoxia had been established continued for hours. Biochemical support for ischemia after wounding was given by Locke (30). In their studies on the wounded spinal cord, lactate increased from a control value of 3.65 mg/kg to 5.5 mg/kg. Using a circulatory arrest model to stop local spinal cord blood flow, these authors established that the tissue lactate rose as the blood flow in the cord decreased. Lactate accumulated during tissue ischemia from a conversion of aerobic to anaerobic metabolism and from inadequate washout of the metabolite due to poor tissue perfusion. Totally ischemic spinal cord tissue lactate was elevated to 14.33 mg/kg 10 minutes after a circulatory arrest and continued at that level throughout a 30 minute observation period. By correlating rising lactate levels in circulatory arrest with those of spinal trauma, the authors feel their data support the hypothesis of localized cord ischemia as the genesis of post-traumatic parenchymal cord lesions. The variance in the injury and ischemia lactate levels are considerable, however, so a direct comparison of injury and ischemia cannot be made.

The essence of an ischemic insult is substrate shortage. Spinal cord function requires energy derived mainly from oxidative glucose metabolism. Much of the energy of this oxidation is trapped in high energy phosphate bonds of adenosine triphosphate (ATP) and phosphocreatine (PC). This stored energy is available for a variety of cellular processes.

It has been speculated that much of the neuronal energy consumption is utilized for active transport of ions to sustain and restore membrane potentials discharged during the process of excitation and conduction. The cell transfers high energy phosphate energy into transmembrane electrochemical gradients. These gradients are subsequently utilized to power electrical activity and transport other molecules across the cellular membrane.

There is a continuing gap in our understanding about events that occur between the initial mechanical and subsequent ischemic insult and the subsequent cellular dysfunction and death. At some critial point ischemic cellular changes can no longer be reversed by restitution of flow, even if energy stores are returned to normal by reperfusion. The reason for continued lack of function following resupply of necessary substrates is unknown. Ischemia appears to trigger a chain of metabolic events ultimately resulting in a decreased cellular store of energy and finally in an inability to regenerate these stores.

The metabolic response to complete ischemia has been studied in the mouse brain by Lowry (31). Glucose utilization increased 10 times normal two seconds following the onset of ischemia. This indicated that control mechanisms activate glycolysis nearly instantaneously. Lactate was formed at a rate 10 times normal from pyruvate. The increased glycolysis did not appear to be associated with increased O_2 consumption. Therefore, the cellular reaction to complete ischemia is rapid and is sensitive to shortages of oxygen.

Since ATP production is limited during anaerobic glycolysis high energy phosphate reserves are rapidly utilized. The normal ATP utilization rate is 30 m-moles/kg/min. This is calculated from an O_2 utilization in rats of 10 ml O_2/100 gm/min (32,33). High energy phosphate reserves (including ATP generated from anaerobic glycolysis of carbohydrate reserves) total only 10 m-moles/kg. High energy phosphate stores will therefore be rapidly depleted if ATP utilization continues unchanged, and are exhausted within one minute of decapitation. The high rate of energy consumption relative to the small reserves account for the rapidity of energy failure during the complete ischemia.

Oligemia, a partial reduction in flow, has been compared to ischemia, a complete interruption of flow by Welsh et al (34-36). Above a critical perfusion pressure level ATP levels were maintained. Within a narrow range of decreased blood flow, ATP dropped rapidly to low levels, first in discrete cerebral regions, then throughout the brain. Similar effects have been noted following

impact injury to the spinal cord. Yashon (37) examined the ATP levels in canine cord as early as one hour following impact injury, and found them to be reduced. Raimondi (38) found ATP stores to be negligible 24 hours after impact injury to the feline cord. Some if not all of the observed reduction in ATP may be due to the known associated reductions in blood flow accompanying impact injury.

Reduction of membranes of the cytochrome chain occurs rapidly after ischemia. It is the first or most sensitive indicator of a disturbance in cellular respiration. Reduced cytochrome can be detected fluorometrically within a few seconds of decapitation (39) or nitrogen breathing (40). The fluorometric signal originates from NADH, the initial member of the cytochrome chain, which increases rapidly in the presence of ischemia.

Ischemic regions of brain have been visually identified in frozen tissue by virtue of NADH fluorescence (41). Precise metabolic concentrations must be determined by chemical means. A similar histochemical technique has been developed to depict regional tissue variations of ATP (42). The application of these techniques to the issues addressed in this section should prove a powerful tool in the analysis of ischemic change in grey matter.

It has been argued that an alteration of metabolism in selectively vulnerable areas alone (i.e. microregion of the injury) might be responsible for a severe disturbance in neural function. Under these circumstances overall estimates of metabolism might be relatively normal. Welsh and O'Connor (41) have demonstrated that cerebral grey matter responds to threshold levels of ischemia with high regional variability in frozen tissue pyridine nucleotidefluorescence. Interestingly, the relative decrement in energy stores (ATP, PC, NADH) was higher in white than grey following such oligemic insults. If these facts are true then our approach to the study of metabolic changes in ischemic spinal cord must of necessity be highly regional.

Although grey matter has classically been regarded as the more sensitive component of the brain in ischemic hypoxia, pure white matter lesions have been identified in both experimental animals (43 a & b) (1), and man (44). It is well established that chronic mild hypoxia-hypertension, as best exemplified by carbon monoxide poisoning, primarily affects white matter, with sparing of the grey matter. Recently it has been shown that mild ischemia, if prolonged for 1 hours may irreversibly damage the white matter, yet not produce changes in high energy metabolites in the grey matter (1). The underlying mechanisms may involve the relative balance between flow and metabolism in the white and grey matter respectively.

A differential sensitivity of white matter tracts in their peripheral location has not been demonstrated in the experimental animal, although it is suggested by pathologic analysis of a single case of carbon monoxide poisoning in man (44). VanHarrevel (45) and Gelfan and Tarlov (46), and Krough (47) have demonstrated zones of hypoxic vulnerability in the spinal cord grey matter. The heterogenous response to ischemia, demonstrated by Welsh, O'Connor and Langfitt (41) in the cerebral cortex, has not been investigated in the spinal cord grey matter. However, an underlying substrate of differential sensitivity appears to be present.

From studies recently completed in this laboratory it appears that the relationship between the degree of ischemia and tissue damage is complex. Global ischemia does not have the anticipated aggravating effect upon acutely injured cord tissue, when compared to tissues which are partially ischemic (oligemia). The progress of cellular lysis was studied utilizing acid phosphatase, a lysozomal enzyme, as a marker. When subjected to total ischemia, the injured spinal cord neurones follow the same temporal course as do non-injured tissues. In order to better define this paradoxical state wherein relative ischemia (as exists in injured tissues) hastens cell death, while global ischemia acts conversely and in a relatively protective manner, we designed in vivo experiments to further retard the already embarrassed traumatic circulation. Prior to wounding the intrathoracic aorta was ligated distal to the subclavian artery. The two hour post ligation injury experiment indicate significant acute protection against lesion development of the injured spinal cord by aortic ligation. In this group of animals, blood flow was found to be 9% of normal control flow values, while injury alone reduced it to only 40% of normal. To express either global or profound ischemia as "protective" can of course be taken in a restricted sense only -- that is, in terms of cellular lysis retardation. Since the essence of an ischemia injury is a shortage of available energy, the results suggest that for cellular lysis to proceed there must be involvement of active metabolic processes which are "sparked" by oligemia and which are diminished by total circulatory arrest. We have shown that major cellular metabolic stimulation occurs within minutes of the injury. The protection against rapid cellular loss afforded by profound ischemia was unexpected. Perhaps the most rational explanation for this set of events is metabolic stimulation coupled with a critical degree of ischemia. Cellular hypermetabolism proceeds but only at short term expense of cellular integrity. The post traumatic cell lysis is, therefore, an active process blocked by severe ischemia.

During a nerve impulse sodium enters nerve cells and potassium (K^+) leaks out. With the great packing density of neurons in the spinal cord, intensive activity may induce an accumulation of extracellular K^+ which causes depolarization of adjacent neurons and therefore blockade of conducted impulses. Following impact injury to the cord, there is an increase of K^+ in the fluid bathing the injured segment (48). Potassium is transported across the cell membrane by an active process requiring energy. A membrane bound enzyme Na^+-K^+ activated ATPase assists in the transport. Bingham (49) has shown that following impact injury

the enzyme to be inactivated or depleted. The exact mechanism for this is unknown. Klatzo (50) has also demonstrated depletion or inactivation of the enzyme in ischemic gerbil brain. Ischemia in the post impacted cord could play a role in the increase of extra-cellular potassium seen following impact.

Neurogenic Factors

Studies conducted in this laboratory have implicated neurogenic factors, specifically, the spinal cord agrenergic system as playing some role in the etiology and propagation of local vasoconstriction and hence failure of the microcirculation. These observations led to the hypothesis that the THN characteristic of nervous tissue degeneration following spinal cord injury (SCI) is causally related to an increased elaboration (release) of the vasoactive agent norepinephrine (NE) onto the local vasculature resulting in a prolonged vasoconstriction, ischemia, hypoxia, and ultimately cellular death. Other laboratories have since suggested a similar mechanism(s) for serotonin (5HT) (51,52,53). Histamine has also been implicated as interacting in the pathological process, although possibly through a different mechanism (54). Recent data from this laboratory demonstrate a significant alteration in both excitatory and inhibitory amino acid transmitters at the injury site. We propose that all of these neurohumoral agents may be involved to some extent in the initiation and propagation of pathyphysiologic events that ultimately lead to THN. These agents can exert influences at both the vascular and parenchymal level and, when acting in concert, they may act in a synergistic manner whereby the response is more than the sum of the individual ones.

The adrenergic innervation of spinal cord parenchyma and blood vessels has been extensively studied for normal and traumatized cat cord by this laboratory. The fluorescence histochemical technique was employed and indicated that while generally very high concentrations of catecholamines (CA) are clustered about all the spinal cord horn areas, the greatest CA aggregate found in any thoracic region occurs within the intermediolateral grey column (ILG) (55,56,57). Other studies indicated that many cat cord blood vessels also receive adrenergic input, as evidenced by the presence of surrounding plexes of CA nerve terminals in close association with the vascular smooth muscle (56,57,58). Both extra and intramedullary vessels exhibit input. The extramedullary vessels (in the ventromedian sulcus of subarachnoid position) do not exhibit catecholamine fluorescence after chronic root section but were unaffected two weeks after spinal cord transection at a higher level. Their input was therefore adjudged to have originated from the sympathetic ganglia. This extramedullary vascular innervation is well known, and has been demonstrated for a number of different species (56,59,60). However, in addition, to these findings, intramedullary (parenchymal) vessels demonstrating associated adrenergic fibers were found in both the grey and white matter. The white matter vessels were more extensively innervated than those in the grey. In contrast to the findings for extramedullary vessels, this innervation of the parenchymal vessels was interrupted by cephalad cord section as evidenced by the absence of fluorescent terminals in the parenchymal cord vessels below the transection. Therefore, it appears likely that these fibers are part of the descending bulbospinal adrenergic fiber system (A1) first described by the Swedish group (61) and later confirmed by this and other laboratories (56,62). In those studies, adrenergic fibers were described as part of a monoaminergic fiber system originating in the pons with terminals in both the anterior, lateral and posterior horns. To date there is scant evidence to indicate whether the adrenergic input to spinal cord vessels represents a true functional innervation or not. A recent study by Kobrine suggest a functional adrenergic innervation, although he feels the origin of the fibers to be from the peripheral sympathetic system (64).

While further investigation is necessary to elucidate the exact role of adrenergic vascular relationship, the data obtained thus far indicate that a potential for a direct adrenergic vascular influence does exist.

Catecholamine Histofluorescence After Spinal Cord Injury

Studies from this laboratory have shown that following spinal cord trauma, a number of striking morphological differences were observed in the adrenergic nerve terminal pattern within and near the injury site within the first two hours following trauma:

1. At the injury site, a prominent fluorescent CA terminal network was noted in association with both the grey and white matter vasculature. This network was much more extensive in numbers and individual brilliance than ever observed in uninjured controls, or in sections 1 cm proximal (T6) or 1 cm distal (T9) to the injury site. This led us to suggest that the alterations in the pattern of the adrenergic vascular terminals following spinal cord injury may reflect increased adrenergic activity which could play a significant role in the mechanism(s) or progressive hemorrhage and necrosis attending injury.

2. The histochemical studies also revealed dense fluorescence associated with regions of the injured grey and white cord parenchyma, where they are rarely, if ever found in uninjured animals.

The most impressive histofluorescent finding in terms of a neurotransmitter vascular relationship is the consistent finding of increased CAF is an association with the injured grey and white tissue vasculature. By this method, however, it is impossible to determine whether the source of this increase is endogenous to these vessels, or whether the CAF is of another origin. If the majority of the CA is parenchymal, a vascular related THN from this source is predicated on the hypothesis that the neurotransmitter is able to diffuse away from

its normal cellular environment to make abnormal contact with the adjacent microvasculature in response to the injury. This is not an unreasonable hypothesis in view of the data of Descarries, who has demonstrated that even under normal physiological conditions, terminal release of central monoamines is not necessarily restricted to discrete, adjacent synapses and may reach relatively diffuse targets (63). The increased CAF observed at the injury site is indicative of an increase in CA concentration only at that high highly specific region: the total tissue CA concentration may in fact be either unchanged or even depressed. Catecholamines may also reach the central vasculature from the circulation as well, as has been previously proposed by other investigators (65,66).

After SCI, the most prominent early regional fluorescent increase was observed in the intermediolateral grey matter (ILG). We reasoned that if NE is causally related to THN, the first appearances of tissue assault should correlate with this pattern. In a study involving over 100 animals, THN began almost exclusively in the grey matter, and the initial development of active necrosis uniquely involved in the ILG matter in 95% of the injured cords. Furthermore, as the necrotic lesion enlarges, it is continuously surrounded by an insidious halo of highly fluorescent and microspectrometrically documented authentic CA.

This laboratory initially reported a significant increase in NE at the injury site following SCI (500 gm/cm) (68). Subsequent studies using the same injury methodology but a different, more specific biochemical technique indicated that NE levels were generally depressed over the first four hours post trauma (57).

The latter studies indicated that the preliminary studies were in positive error. We have concluded that the original (solvent extraction) method was in positive error probably by detecting trauma induced substances which react at the NE wave length. The greater specificity of the second technique proved that the interfering substance(s) was neither NE nor an authentic CA. Support for this concept was given by Shoultz and DeLuca (69,70) who detected a similar increase (although of lesser magnitude) following SCI utilizing a solvent extraction technique. Furthermore, this laboratory tested a number of CA like compounds and found several to yield positive interference at the NE peak of the original method. (For instance, normetanephrine (NM), an O-methylated metabolite of NE, gave a positive interference in this assay but not in the second.) At this time several other laboratories were unable to agree whether NE level alterations occur or not. Decreased (71,72) increased (73,74), no change (75,76,77) and extensive time related variations were observed in NE levels (77). There was also considerable diagreement on the fate of DA levels following SCI (71,75,76,77).

Although these wide inter-laboratory variations are puzzling at first glance, they are not totally inexplicable when it is considered that the various laboratories (including ours) intermixed four different animal species and three different injury magnitudes, sometimes measured only single or different time periods, and selected a wide range of sample sizes and analytical techniques.

The selection of sample size taken for biochemical analysis is probably the single most important error producing these variable data. This is so because the necrotizing lesion is a progressive phenomenon which means any attendant biochemical alterations are a function of both time and distance (tissue matter volume). Since the actual injured tissue (as evaluated by THN) initially involved is extremely small and specific (= 3-mm^3 after 1-2 hours), measurements utilizing tissue samples from 0.5-1.0 length (100-200 mm^3) are diluted by a factor of 30-70X at this time period as far as the active necrotizing area is concerned. Therefore, even relatively large amine changes within the active region will be misrepresentatively diluted by these procedures. In fact, in a progressive, pathologically active tissue, there are (for practical purposes) at least 6 distinct biochemical compartments: the completely degenerated region(s) the actively necrotizing region(s) and the intact region, in both the functionally and biochemically distinct grey and white area. All of these regions will fall within a 0.5-1.0 cm sample, during the first few hours following trauma.

The second most important variable is probably the injury magnitude. This laboratory showed that with 600 gm/cm injuries NE levels decreased with a significantly steeper rate of decline than following 500 g/cm injuries, indicating that the adrenergic response to trauma is clearly magnitude dependent (57,78). In this regard, it is interesting to note that alterations in post traumatic spinal cord blood flow are also magnitude dependent. Bingham et al demonstrated that when the injury force is increased from 300 to 400 g/cm in the primate, blood flow in both the grey and white matter is significantly decreased with increased magnitude of trauma (79,80). There is therefore, a similar response to magnitude of injury for both NE and blood flow. From these studies it cannot be determined whether there is a causal relationship or not, but the similarity is important in context of the present proposal. Bingham et al also determined that the force needed to produce irreversible paralysis in the monkey was less than that required in the cat (400 g/cm versus 500 g/cm) respectively (80). He also determined that the NE concentration in the monkey cord was almost twice that of the cat (71). This suggests that there may be more than a causal relationship between the concentration of endogenous NE and the sensitivity of the experimental animal to trauma.

Therefore, many of the above disagreements can be explained in terms of various injury methods, magnitudes, and sampling parameters. Consequently, it is obvious that:

1. The injury method and magnitude must be taken into account when different studies are compared.

2. Accurate histological characteristics of the exact injury locale must be made.

3. Small, discrete regional samples be taken at the injury site, and carefully identified as to regional and pathologic state and compared with precisely similar regions in their respective controls.

Recent Studies

Two relatively recent studies bear out this latter suggestion for the post traumatic behavior of NE and 5HT in 1 mm subsections by radioenzymatic techniques taken along the rostral caudal axis of the traumatized cord, there are no significant alterations in NE tissue concentrations until the region 1 mm immediately above and adjacent the trauma site is reached: at this point, the NE levels show an initial decline of 20%, then within the 1 mm trauma site itself, there is a further steeper decline of 60% for a total depression of 80%, an equally steep partial recovery below the injury site, and complete recovery beyond the 1 mm adjacent, below region. These data indicate that alterations in NE occur that are both highly regional, and massive. On the second study, Zivin et al have reported similar findings following distortion trauma to the rabbit cord. These investigators took small regional punch samples and determined that as early as 5 minutes following trauma, both NE and 5HT were not only significantly decreased within the vicinity of the injury, but undetectable in some areas. By direct calculation, from turnover studies, NE has a nnormal halt-life of from 2-4 hours. Therefore, an 80% decrease in NE within one hour must represent a massive transmitter release. Presumably, the same condition also obtains for 5HT, although precise cord 5HT turnover times are not as well defined as for ME.

While the more recent data strongly suggests a rapid and substantial release of NE and probably 5HT from their sites of storage, there is no evidence to indicate that NE or 5HT necessarily reach the extra-cellular environment. Since 5HT and NE are both stored in vesicles within the nerve terminals, it is possible that the neurotransmitters are released from the storage vesicles into the nerve ending cytoplasm. If this occurred, they could be detoxified (oxidized) by intracellular monoamine oxidase in a manner analogous to that following the drug reserpine. While there is at present no biochemical evidence for or against an extracellular transmitter release, such a release is implied in the remarkable cyclic nucleotide response described in Section IV. Cyclic AMP increased to several times its control value over the first 5 minutes post trauma, suggesting a significant stimulation of adenylcyclase. An extracellular release of NE and 5HT is often associated with a stimulation of adenylcyclase and concomittant rise in cAMP (81,82). The close correlation of neurotransmitter and cAMP changes, and the functional interrelationships between the two, strongly suggest a cause-effect relationship. On the other hand, the cAMP elevation may be due to an inhibition of the cAMP catabolizing enzyme, phosphodiesterase. But in this time frame, there is also a marked decrease in ATP levels. Since ATP is a direct cAMP precursor, it is quite possible that the rapid ATP decrease represents, at least in part, an active cAMP synthesis with ATP consumption. Although the relative alterations in ATP and cAMP are not conclusive evidence of adenylcyclase stimulation, the extent of the alterations and the close temporal correlation are strongly suggestive of a de novo synthesis of cAMP (stimulation of adenylcyclase) rather than a prevention of break-sequence. Extracellular potassium is capable of stimulating adenylcyclase directly and may be in part responsible for the observed cAMP production. At the same time, extracellular potassium can also induce neurotransmitter release. Although potassium release has been reported to occur after SCI, neither the regional pattern of this release, nor its metabolic significance have as yet been established. Kogure et al found changes for NE, ATP, and cAMP in ischemic brain that are remarkably similar to these we have noted for spinal cord injury (83). In ischemic brain, NE and ATP fell substantially within two minutes while there was a concomitant cAMP increase.

From these observations they concluded that ischemia causes NE release which induced cAMP formation and either action might be a factor in promoting the cortical vasoconstriction that occurs following CNS vascular embolization. The mechanism for release of the centrally derived NE is unknown. It is possible that a peripheral penetration of NE through the ruptured blood brain barrier (BBB) may induce an initial vasoconstriction that in turn induces a release of stored NE by secondary mechanisms. The release may also be directly related to the trauma itself, since irritation of nervous tissue is known to initiate a release of NE (84,85). Once the process of vasoconstriction and ischemia is begun, potassium release may also occur, causing a further release of CA. The development of local hypoxia may also continue the sequence by causing a NET release of both parenchymal related and vascular NE. Local hypoxia contributes to net neurotransmitter release by blockade of the normal reuptake mechanisms (86). Serotonin of peripheral (platelet) or central (parenchymal) and possibly vascular origin (87) may also contribute significantly to the overall postulated vasoconstriction phenomena. Thus a very complex and extremely active cycle can be initiated from more than one source. While the evidence is far from complete, the available data supports a hypothesis of neurotransmitter release of some magnitude. Assuming that neurotransmitter release and/or invasion is causally related to post traumatic vasoconstriction, there are a number of further questions lthat must be addressed. Is transmitter release and/or invasion a transient and restricted phenomenon unique to a few minutes after the blow or can release by sustained and perpetuated by synthesis in this environment? If synthesis occurs is it regional (to the as yet preserved edge of the lesion) and can it be correlated with regional blood flow alterations or cellular pathophysiology? Since the nerve terminal(s) containing the neurotransmitters are

contained mainly in the grey material, can a transmitter related phenomenon be rationalized for the white matter? an estimation of the turnover, or synthesis and utilization of the transmitter(s) known to be involved should provide some information regarding these questions.

Peripheral Transmitters

Peripheral CA

As previously mentioned, biochemical studies aimed at defining the role of central neurotransmitters in SCI can be obscured by the fact that these agents may invade the injured cord region from circulating sources. We have recently detected some early alterations in CA at the injury site that indicate that peripheral CA do in fact invade the injury site, at least at the ultra acute time periods. When 5 mm cross sections were taken through the injury site, 1, 2, and 5, 10 minutes after trauma, measured for NE, DA and E and compared to remote thoracic control sections of the same size, there was a significant ($P = 0.01$) increase in NE and E at the injury site in the two minute but not at any of the other time periods. The appearance of E, not normally observed in significant quantities in the cord, imply a peripheral source for these two amines. This data suggests that a transient, but highly significant invasion of peripheral CA occurs via the ruptured BBB after trauma. While the significance of this invasion is not as yet known, there may be some link between this finding and the substantial increase in cAMP observations at this time.

An important question that must be addressed is whether NE actually has the overall capability to reduce blood flows to the extent found after SCI, assuming that it can be released in above normal quantities and/or about normally inaccessible sites. One impediment to such a determination is the BBB normally impenetrable by NE. Griffiths has circumvented this impediment by producing a discrete confined rupture in the BBB at the lumbar level, (with small amounts of urea) then injecting graded amounts of NE (0-30 µg) into the vessel just proximal to the rupture. The effect of NE on the blood flow is detected by measuring the flow before and after NE by hydrogen clearance techniques. When 30 µg of NE is injected, spinal cord blood flow is reduced to 10% or less of normal, 12 µg approximately threshold. This study does not, of course, allow us to determine whether CA of central origin can cause the same effect, but it does indicate that NE of novel origin. It can elicit conditions closely mimicking those observed after traumatic spinal cord injury, i.e., comprised blood flow. This work also suggests that rupture of the blood brain barrier may allow circulating agents, such as NE and platelet borne serotonin, that are normally unable to reach the spinal cord tissue, accessibility to the cord where they may exert vasogenic (and/or parenchymal) effects. Apparently, adrenergic receptors in the vascular wall are normally sequestered from peripheral been reported by Vise (65) and Felton (66) who presented evidence for a trauma related increase in access. Data in support of such a mechanism has cord CA from peripheral sources. If CA are invading the injured cord region from the circulation, such an invasion would complicate the meaning of the measurements of these transmitters at the injury site. This is especially true in face of falling NE levels of a central source. If CA levels are falling due to central release of CA, and increasing due to peripheral invasion, it is theoretically possible to measure no change in CA levels, while in fact, a substantial tissue invasion of these amines may obtain.

Peripheral 5HT

There is indirect evidence that 5HT of peripheral origin may influence the injured cord. Brodner et al described a significant increase of 5HT in the CSF of the cat 1 hour after 500 g/cm injury. From this data they postulated that release of 5HT from platelets after trauma may be responsible for the onset of vasoconstriction and altered perfusion in the intrinsic vessels of the spinal cord, an idea also proposed by others (88). On the other hand the CSF 5HT may derive, as the authors also state, from the neural tissue itself. If this data is taken together with that of Zivin et al (72), who demonstrated a substantial decrease in 5HT (and NE) at the injury site after SCI, it could be interpreted as implying that the increased 5HT observed by the former investigators might actually be a reflection of the decrease (release) in 5HT observed by the latter group. This is another issue in need of resolution especially in view of the fact in a subsequent study by this group the decreased blood flow after SCI was partially ameliorated by pharmacologic blockade of the 5HT response (89).

Culpability of NE to Induce Pathologic Influences

(Microinjection Studies)

Norepinephrine has the inherent capability of causing hemorrhagic necrosis when placed in the vicinity of cord microvasculature. Injection studies from this laboratory have shown that hemorrhages and necrosis follow NE injections into cord grey matter. These histopathologic lesions from NE are accurate reproductions of those following trauma. Although an effective NE concentration of 35 ug was required to accomplish lesions Iverson states that because of highly efficient NE uptake mechanisms, it would require at least 100 times as much exogenous NE to accomplish the same effect as a single unit of endogenous NE (90). Since grey matter NE concentration averages approximately 0.4 ug/g and is found in even higher concentration in discrete areas, the experimentally injected dose reasonably approximates potentially available wounded cord NE. Assuming a 100/1 ratio and total release, the endogenous effect would approximate 40 ug+ of injected material. This concentration of material would cause a large central grey lesion, quite comparable in size and detail to a severely injured two hour cord. This is a highly simplified approximation, of course, since many factors can further complicate relative

exogenous to endogenous extrapolations but the approximation indicates that NE has the potential to assault spinal nervous tissue in the face of an exaggerated release.

Other studies, in which cats were wounded prior to microinjection of NE, show that even lesser doses of NE (10 ug) are able to cause tissue damage after as little as 1 hour post-trauma time period. This damage is comparable to necrosis in uninjected cats 6-12 hours post-injury, and includes considerable necrosis of the white matter. In addition, when tracer amounts of tritum label were included in the study, the areas of greatest tissue necrosis were circumscribed by intense concentrations of ^{3}HNE. Four circumstances are evidence from this study.

1. NE has the propensity to induce nervous tissue destruction in the spinal cord.

2. NE (at least that of exogenous origin) has even greater destructive potential when exposed to the injured cord medium.

3. White matter is not exempt from this destructive potential.

4. ^{3}HNE is not found randomly distributed throughout the injured cord, but highly concentrated, and then in regions of greatest tissue damage. The ^{3}HNE is rarely seen in the association in noninjured animals.

This may indicate that:

1 Normal uptake mechanisms may be inhibited, even in the first hour post injury.

2. The NE selectivity concentrated in areas of greatest structural weakness may represent a causal contribution to that weakness.

3. The NE surrounding these tissue areas look very much like the histofluorescent CA pattern. Therefore, three separate techniques histofluorescence, autoradiography, and histopathology all demonstrate that CA and necrosis are not morphologically related.

From this data, it is not unreasonble to speculate that subtle cellular disruptions caused by the initial mechanical stresses, while not debilitating (or the decreased blood flow after SCI) was partially ameliorated by pharmacologic blockade of the 5HT response (89).

Pharmacology

A number of pharmacologic agents have been shown to protect the injured spinal cord. Reserpine, a drug that has both potent antiadrenergic and antiserodanergic effects (91) protects against THN (57) and helps preserve cord function (57,92). Alphamethyltyrosine, and adrenergic synthesis inhibitor, was reported to protect against THN in the cat (93), but not in the dog (94), and only in the grey matter of the monkey (95). Parachlorophynylalanine a 5HT synthesis inhibitor significantly improved blood flow through the injured cord and phenoxybenzamine (PB) a specific adrenergic antagonist, has been shown to prohibit post-traumatic necrosis (89) hemorrhage (97) and functional loss (94) by three different laboratories. There is an honest, but as yet unresolved disagreement as to the mechanisms of phenoxybenzamine protection. Rouwe et al (97) feel that PB protects by blocking the systems hypertensive response that follows trauma while we feel PB protects at the local, injured level (98). (One of the specific aims of this proposal will be to determine the exact mechanism of PB protection.) The combined data indicate that pharmacologic intervention protects the injured cord, and moreover, it protects against a number of specific pathologic occurrences. The data also supports the suggestion that NE and 5HT both influence SCI.

We feel that pharmacologic intervention is the key to both unraveling the mechanistic factors underlying SCI, and to therapy aimed to eventually preserving cord fucntion. But in face of serious vascular compromise, it is obvious that conventional routes of administeration are no longer valid. Therefore, in order to realistically determine the efficiency of pharmacologic agents, a comprehensive dose-route, dose-response investigation must be conducted before a given agent can be discarded as ineffective. This contention is supported by the findings with PB. Where PB has been utilized in SCI, the experimental animals were pretreated; before injury and the consequent vascular stasis is intiated. Unfortunately, very few comprehensive pharmacologic studies have been conducted in the injured cord to date.

Amino Acids

In the past several years considerable evidence has been obtained in support of the concept that a number of endogenous amino acids are active neurotransmitters in the mammalian CNS. Gamma-aminobutyric acid (GABA), glycine, alpha and beta-alanine and taurine, among others have all been postulated as inhibitory CSN transmitters, while glutamate and aspartate have been implicated as excitatory neurotransmitters. Although GABA is generally considered to be more important in the brain, in the spinal cord, GABA seems to be an inhibitory transmitter of the Golgi type II interneurons and dorsal column nuclei (109). Glycine is an even more important inhibitiory agent in the mammalian spinal cord and is an extremely potent hyperpolarizing agent in both spinal motor neurons and spinal intraneurons (110). Although the transmitter role for other postulated inhibitory amino acids have not been well characterized for the spinal cord, there is little doubt that these agents can exert inhibitory influences if they are made available to some nerve parenchyma. The same can be said relative to the excitatory potential of aspartate and glutamate. An abundance of evidence, much too extensive to review here, attest to the potential of aspartate and glutamate as excitatory transmitters on a large variety of central nerve cells. In the amino acid section, we have described significant post traumatic alterations of a number of inhibitory and excitatory neurotrans-

mitters in both the grey and white matter, one hour following SCI. Although the exact role of these alterations are not known at this time, it is difficult to conceive that significant alterations (both increased and decreased levels of inhibitory neurotransmitters, and decreased levels of both leading excitatory AA neurotransmitter candidates ((in both the grey and white matter)) are without neuro-regulatory consequence).

A final amino acid that has been recognized recently as a postulated neurotransmitter is taurine. In addition to fulfilling many criteria as an inhibitory neurotransmitter in the mammalian CNS, taurine has been shown to exhibit significant control over potassium and calcium flux, especially under conditions where electrolyte imbalances exist. Furthermore, taurine has been reported to influence the release of central NE stores (112). In review of the pathophysiologic condition of the injured cord, the behavior of this AA in the injured cord should be investigated.

The behavior of the postulated AA neurotransmitters will be determined as a natural spin off from the AA study although the data concerning AA having a neurotransmitter function will be interpreted in conjunction with the other neurotransmitter studies in this section.

Direct Cellular Toxicity

In addition to their vasoactivity, the biogenic amine neurotransmitter, especially the CA, are well known for their metabolic effects. If these agents were to stimulate cell metabolism in the injured tissues at a time when cellular energy stores are already at precariously low levels, the process could drive the cells to a premature death. This concept has been previously proposed for other nervous tissue assaults (67) and there is a report that the CA norepinephrine can cause direct cellular toxicity independent of ischemia induced mechanisms (113).

Supra Spinal Effects

Spinal cord injury is often accompanied by mild to severe affective disorders, especially depression (114). It is not known whether these disorders are a psychological reaction to the loss of motor function, or whether they are due to a supra spinal organic alteration. Data from this laboratory indicate that significant neurochemical alterations occur in NE in the cat brain, following SCI. Since defects in NE metabolism have been suggested in numerous studies as being related to depression, we feel studies should be carried out to further describe remote supra spinal neurochemical alterations following SCI, especially in the chronic time peirods after trauma.

Edema

The role played by edema in the pathophysiology that follows acute SCI is presently unknown. Before this role can be appropriately investigated, a reasonably accurate knowledge of the extent and exact locale of the edema needs to be obtained. Although the edema associated with SCI has been grossly quantitated, the methods used to date have lacked the sensitivity required to quantify edema on a specific regional basis (115,116). Furthermore, if a relatively steep quantitative gradient of edema were to exist within the injured cord, artifactual small edema values could result as a consequence of the larger, heterogenous tissue samples required by less sensitive methodology. This shortcoming was circumvented by coupling the sensitive specific methodology. This shortcoming was circumvented by coupling the sensitive specific gravity column method of Loury (117) as modified by Nelson (118) with a tissue punch technique for edema determination. Studies using this technique show that regional edema is as high as 10 times that observed with conventional techniques. The data indicates that after SCI, tissue edema reaches far greater proportions than had been previously thought and suggest that edema may play a significant role in SCI.

In summary, work and concepts have been described to establish the degree to which research has contributed to our understanding about the pathophysiologic response to spinal cord injury. These philosophies and data have moved us substantially away from the mechanical aspect of wounded neural tissue into the metabolic aspects leading to the metabolic cascade which is initiated by trauma, but perpetuated long after the insult has passed. The fundamental question yet to be answered is can we by anti-metabolite therapy prevent progression of THN and thereby preserve spinal cord function?

We are preparing to do clinical studies on the most promising pharmacologic treatments.

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SPECIAL SESSION/SÉANCE SPÉCIALE 5

NEW MODELS IN REHABILITATION/

NOUVEAUX MODÈLES DE RÉADAPTATION

Chairperson/Président:

R. Levy
Université de Montréal
Montréal, Canada

NEW MODELS IN REHABILITATION

Chairman: R. Levy
Panel: G. Kielhofner, D. Roy, I. Zola and J. Derkson

Introduction

(Re)habilitation is a complex social phenomenon which includes, to name but a few, individual rights, socio-cultural values, socio-technical research and institutional structures in the form of clinical practice and service delivery. As such, it is a field which is amenable to analysis from a number of perspectives. The following papers collectively focus on new approaches in (re) habilitation from historical-paradigmatic, socio-psychological, socio-political, socio-ethical and socio-technological perspectives. They clearly distinguish the biomedical model of (re)habilitation from the evolving systemic models and acknowledge that the concepts of health, the principles of medicine, the practice of (re)habilitation and the structures of individual participation are presently undergoing a process of fundamental change.

Gary Kielhofner sets the stage with a general overview of the emerging field of (re)habilitation in his paper "A Paradigmatic View of Rehabilitation". He skilfully takes us through the evolution of thought in (re)habilitation from its origins in the 18th and 19th centuries to the present. He traces the influence of the mechanistic paradigm on science and the impact of scientific reductionism on the development of the biomedical model. The reasons for the failure of reductionism in (re)habilitation are outlined, and the present day approach based on general system theory is introduced. Dr. Kielhofner strongly supports the view that the systemic paradigm is a desirable and logical conceptual basis for the development of new models of (re)habilitation, and includes as an example of such an approach, his model of Human Occupation. His paper succinctly documents the historical development of the bio-medical model of (re)habilitation and illustrates the present struggle of the (re)habilitation profession to emancipate itself from the model's limiting reductionism.

David Roy uncovers a dimension of (re)habilitation that is rarely discussed. His paper entitled "Transcendence Towards an Ethics of Rehabilitation" weaves a facinating tapistry of fundamental referents which are at the very core of human reflection and action. Dr. Roy promotes the need for "world order" thinking not simply as an ideal, but as an operational process to achieve the goals of humanity and to honour their values. Within this viewpoint the process of how we understand health, it's maintenance, it's pattern of relationships and it's institutions is exemplified. He also leads us towards an understanding of an ethics of (re)habilitation by discussing the phenomenology of the body, the source of power and control over our world, the concepts of integrity and suffering and the general goals of (re)habilitation. He completes his paper with an outline of why (re)habilitation is in fact a macroethical challenge and why the concepts of transcendence and integrity are necessary for the development of a foundation of ethics of (re)habilitation.

Irving Zola in his paper "Disincentives to Independent Living" shifts the emphasis of discussion to socio-psychological concerns. His paper describes the inherent difficulties in the past of mainstreaming individuals with chronic disabilities and how these same difficulties continue to manifest themselves in the current emerging biopsychosocial model of (re)habilitation. In his inimitable way Dr. Zola describes the notions of individual independence, self-reliance and the need for individual risk-taking through a series of enlightening personal anecdotes. He discusses the contradiction between the much esteemed value of self-reliance of the individual and the reluctance of the (re)habilitation establishment to accept the disabled citizen as an equal partner in his own (re)habilitation. This conflict of values is further emphasized in society's general over-reliance on technology and how technology is being used to the point where the very integrity of the individual is in danger of being violated. Irving Zola's message is clear. The new emerging (re)habilitation model, if it is rooted in systemism and holistic attitudes, must transcend the current notion of independence from being a purely physical/technical achievement to include more global socio-psychological dimensions. He thus underlines the need to comprehend the values associated with the modalities of intervention in (re)habilitation by understanding how we think about and how we act within the process of (re)habilitation.

Jim Derkson brings to the fore the socio-political perspectives of future models in his view of the participation of disabled persons in the (re) habilitation process. He clearly and deftly identifies the obstacles to individual participation in terms of attitudes & structures, and proposes a strategy for promoting full participation. This strategy includes the development of models which promote participation in decision making, which is central to full participation, and models for the prevention of attitudinal and structural obstacles. The discussion is then led towards a rationale for the development of, and the significance of, organisations of disabled people which are directed at attaining full participation.

In an attempt to round off the discussion, my own paper sets out to define what is a paradigm and develops a general model of a systemic paradigm. This general model is then used to discuss the strengths and limits of existing and emerging models of (re)habilitation. The biomedical and biopsychosocial models of (re)habilitation are reviewed and their limitations discussed. In both cases the technological dimension is shown to be poorly represented and this factor is emphasized in a discussion on technology and value. The importance of attaining an understanding of the technological modality of any (re)habilitation model in terms of knowledge, organisation, instrumentality and purpose is out-

lined. This is further exemplified in a discussion of individual needs and the inevitable power struggle between technical and value authority within the emerging systemic model of (re)habilitation.

A PARADIGMATIC VIEW OF REHABILITATION

Gary Kielhofner, Dr., P.H., OTR

ABSTRACT - This paper presents an overview of the evolution of thought in rehabilitation documenting the effects of reductionism and the medical model on rehabilitation though and action. General Systems Theory is proposed as an alternative and desirable conceptual basis for rehabilitation and its potential is illustrated through a model currently in use in one rehabilitation discipline.

RÉSUMÉ - Cette communication présente un survol de l'évolution de la pensée en réadaptation et documente les influences du reductionisme et du modèle médical sur la pensée et la pratique en réadaptation. La théorie générale des systèmes est proposée comme une alternative et à la fois une base conceptuelle désirable pour la réadaptation et son potentiel est illustrée par un modèle couramment en vigeur dans une des disciplines de réadaptation.

A number of writers have noted that the field of rehabilitation is currently without an acceptable paradigm (DeJong, 1979; Levy, 1983; Mosey, 1974; Kielhofner & Burke, 1983). The present rehabilitation model is largely a conceptual extension of the medical model, its implied view of health and illness, its reductionist scientific framework and its action implications. Underlying discontent with the conceptual foundation of rehabilitation is a recognition that being a conceptual stepchild of medicine is inadequate for the field of rehabilitation. The medical model is focused on and can operate as an effective conceptual and operational mode in the context of acute illness. However, the recipients of rehabilitation services are chronically ill individuals who seek remediation of or support for coping with residual disability following congenital abnormality, disease or trauma.

Because of the limitations of time and the breadth of the topics I wish to cover and integrate, it will only be possible to give them superficial treatment. The plan of this paper is to briefly articulate the conceptual and historical reasons for rehabilitation's current lack of a viable paradigm by discussion of reductionism in scientific thought and its impact on medicine along with the latter's influence on rehabilitation. In order to chart some direction for future conceptual development in rehabilitation, I will discuss the General System Theory concepts of hierarchy and open systems and demonstrate their use in a model of practice. Finally, I will discuss the implications of this model for understanding physical disability and generating a broader paradigm of rehabilitation.

Reductionist Thought. The doctrine of reductionism has dominated Western intellectual thought since the early achievements of the physical sciences. Reductionism is based on several assumptions about the nature of the world and about how scientists come to know about that world (von Bertalanffy, 1968). These assumptions are: 1) The world may be comprehended by a mechanical analogy. That is, all phenomena are and may be understood as the representation of accumulated cause and effect linear chains of events.
2) Because the world is a vast mechanism, it can be scientifically studied by reducing it to its building blocks or constituents and discovering the causal relationships among these parts; hence the term, reductionism. When the relationships among parts are all added together they will sum up to the explanation of the whole
3) The essence of things always lies below the phenomenological level at which we encounter them in their inner workings. Thus it is correct to reduce phenomena to the actions and interactions of their constituents. From these assumptions we could logically argue that mentation is an epiphenomena resulting from the organized firing of neuronal cells in the brain; that the latter is determined by sub-cellular arrangement and transfer of chemical components; and that these are ultimately reducible to elementary particles with identifiable valences which explain their propensity to combine in certain ways. Such a schema effectively reduces human thought to the play of atoms upon other atoms. While such an extreme doctrine of reductionism would be rejected today by many scholars, thinking along these lines still dominates many fields of thought including the rehabilitation disciplines.

The result of reductionist thought on how we conceptualize the world about us is manifest in our tendency to isolate phenomena from their context, to study phenomena by breaking them down into components effectively ignoring the whole, and to dichotomize phenomena of different types despite their membership in the same system. Examples of this later tendency are mind-body duality and the separation of persons from their environments in our conceptual schemes (Koestler & Mithies, 1969).

Reductionist thought, despite its shortcomings, should not be underestimated. It is a powerful scientific tool that has been critical in shaping the emergence of modern medicine. Criticism of reductionism is not of it as an epistemological strategy per se, but of its inadequacies and limitations for understanding the

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from the medical model which was becoming more and more focused on anatomical, physiological and intrapsychic disturbances and their direct remediation.

While acknowledging the empirical success of rehabilitation, American medicine pressured the rehabilitation disciplines to adopt a scientific approach to their practice. In short, this meant modelling rehabilitation on a reductionist framework.

Here I will comment only on my own analysis of the implications of this in my own field (Kielhofner & Burke, 1983). In response to medicine's challenge to employ a scientific (or reductionist) approach to conceptualizing the role of therapy in rehabilitation, therapists became increasingly uncomfortable with holistic concepts, with the employment of simple daily activities as therapeutic media, and with an orientation to something so intangible as the client's phenomenology as the focus for the rehabilitation process. Instead, therapy (as represented in the literature and practice) increasingly focused on the identification of discrete problems or deficits such as motor or sensory loss with less attention to the implications of such losses for the person's lifestyle, self image, social position and the like. Remediative procedures increasingly appeared that were similar to the intervention model of medicine so that therapists placed patients into more impersonal, passively compliant tasks, took to fabrication and prescription of splints and other mechanical devices and gladly traded their everyday accoutrements such as avocational activities for biomechanical apparati such as deltoid assists, exercise skateboards and the like. This was all done in the name of scientific progress, but its impact was to depersonalize the rehabilitation process and remove the patient from any contact with the commonplace things of everyday life.

The failure of reductionism in rehabilitation.

There are two accounts on which the medical model or reductionist approach to rehabilitation can be deemed inadequate: inappropriateness of the sick role and 2) limitations of reductionistic thinking for conceptualizing the problems and the adaptation requirements of the disabled person. A number of writers have commented upon the inappropriateness of the sick role in rehabilitation (Illich, 1976; DeJong, 1979; Burke, Miyake, Kielhofner and Barris, 1983). As formulated by Parsons, the sick role allows a person relief from the obligations of normal roles in return for compliance to medical interventions and for attempting to get well. However, the disabled person lacks the potential of "getting well" since the impairment is permanent. Further, the passive compliance to medical practitioners in rehabilitation can have the untoward effects of making the disabled person unduly helpless and, leading to a permanent disabled role (DeJong, 1979) characterized by dependence. De Jong (1979) suggests that a self help role may be emerging in the independent living movement. Burke and others (1983) recommend a health apprentice role which stresses partnership between the rehabilitation professional and the disabled person role and gives the latter power to influence the course and desired outcomes of rehabilitation efforts. However, so long as rehabilitation professionals conceptualize their relationship to the disabled person as one of repairing and adjusting or compensating for deficits and disruptions in the bodily functions of the disabled person, it will be impossible for such a role relationship to emerge. Inasmuch as the rehabilitation professional takes his/her identity and instructions for action from the paradigm of the field, that paradigm is critical for the kinds of role relationships that will be possible in rehabilitation. Thus, the second and related consideration is the limitations of reductionist thought in providing a conceptualization of the problems of the disabled person. Because reductionism tends to lead to isolation and fragmentation in perspectives, the focus of rehabilitation efforts has often been on remediation of or substitution for lost movement and sensation, rather than consideration of how these losses may have affected the psychological and social aspects of the individual's life. The latter consideration, however, may affect how the disabled person wishes to reconstruct his or her life and, afterwards, what degree of impairment the physical disability might present and what social and environmental features might need to be adjusted to allow the person to function optimally. Another way of putting the issue is that it is not possible to predict from the level of a cord lesion, or from the severity of spasticity or involuntary movement, or from the type of amputation, what needs the person will have in terms of biomechanical adaptations. If the amputee is a farm worker, the implications for prosthetic selection and training might be vastly different than if he is an artist, and even different than if she is a teenager whose primary concern is appearance and not function. Reductionist analysis is useful for telling us the biomechanical requirements based on losses of motion and normal movement, but it cannot tell us what the person wants to do with a biomechanical aid or replacement, or what its positive or negative significance might be, given the individual's value system. One quadriplegic may find the tenodesis split a welcome assist to functional upper extremity movement, while another rejects it as a symbol of his disabled status and dependence on external devices. I recall observing quadriplegic patients in the hospital during their evening poker game dutifully eschewing their functional splints (which might have increased their ability to physically grasp cards) because they interfered with how one "looked" during the game--that is, with the stylized movements of slapping cards on the table.

General Systems Theory

Although reductionism has been accepted as a scientific doctrine by the physical sciences, life sciences, medicine and rehabilitation, there is throughout a growing discontent with its limitations. In response, there has emerged a movement toward systemic thinking, referred to as General Systems Theory.

General System Theory is an attempt to develop a meta-theoretical language which

complexities of living and thinking phenomena (Boulding, 1968; Koestler & Smithies, 1969; Weiss, 1969) and consequently for guiding the field of rehabilitation.

Reductionism in medicine

Modern medicine is firmly entrenched in the scientific doctrine of reductionism (Brody, 1975). Reductionism in biochemistry and biology forms the foundation of clinical medicine and has significantly augmented the physician's understanding of and control over biochemical processes in the human body. Linear causation is a critical concept for the germ theory of disease and it thus guides thinking about the etiology, prognosis and intervention of illness.

At the same time it has also resulted in a conceptualization of the healing process which is predicated on the mechanistic analogy--i.e., that the human being is essentially a very complex machine to be repaired through the ministrations of the physician. Though articulated for different reasons, Goffman's analysis of the sociological features of the medical model supports the argument that physicians essentially treat human beings as though they were machines. Goffman (1962) points out that medicine has grown with many other occupations in the last two centuries within a work model of shop industry. Like the car repairman, physicians carry on their trade in a workshop suited to rearranging, repairing and replacing component parts. Within the workshop, physicians have the tools and artifacts of their trade about them, all of which are relatively foreign to the everyday life and commonsense knowledge of the client.

Further, the client, in order to receive the service, hands over personal property to the practitioner, placing trust in the practitioner's intervention. For a period of time the owner relinquishes control over that property. In the case of auto mechanics, the owner hands over a car. In the case of medicine, the patient hands over his or her own person. The usual jurisdiction that one has over one's body or mind and its functions are relinquished to the control of the physician who either dictates orders for or directly controls its function. This model of medicine is not without merit. One readily recognizes that if one has an inflamed appendix, a fractured femur, or other acute illnesses that it is generally expeditious to hand over one's body to the physician for management and repair. Aside from having a few minor complaints that one's healer is not compassionate or didn't have much time to talk, one will likely be quite content with the physician's reductionist approach and its typically successful strategy of remediation. However, as I will argue later, this reductionist medical model breaks down when the patient's problem is permanent, when it is disabling or otherwise calls for an adjustment in how the individual lives his or her everyday life.

Historical Overview of Rehabilitation

Many authors locate the progenitors of the rehabilitation movement in the moral treatment era of the 18th and 19th centuries. Moral treatment was originally an approach for rehabilitating emotionally disabled persons and its demise came well before the modern rehabilitation movement in this century. However, its conceptual basis is one that initiated early rehabilitation thinking in the United States and that still rings true as a humanistic and efficacious approach to rehabilitation.

Moral treatment was predicated on the belief that the problems of the emotionally disturbed individual were primarily problems with everyday living (Bockonen, 1972). Persons who during the middle ages had been locked away in institutions, segregated from society, neglected and abused were, in the period of moral treatment, brought into programs or "normal living" which stressed creation of an atmosphere of normal work and play and social relations. The idea of moral treatment was to reestablish the phenomenological connection to everyday life through participation in the life of the rehabilitation setting. Thus active participation of the person in a healthy environment was central to moral treatment.

It is also interesting to note that moral treatment proponents saw disability as emanating from environmental stresses rather than from the person. Remediation thus focused on normalizing the environment and on giving individuals reasons for performing by making available to them the accoutrements of the culture. The ideas of active agency as central to self-regeneration and of the environment as health facilitating were critical themes of moral treatment.

The historical forces which have delivered rehabilitation from this early conceptual orientation to its current form are complex and involve changes in both medicine and rehabilitation, so I will only briefly overview them.

Early North American rehabilitation leaders and writers included Adolph Meyer (1922), William Rush Dunton (1919), and Herbert Hall (1923), American physicians; and Thomas Kidner (1930), a Canadian architect interested in hospital design and the role of activity in convalescence. These authors fashioned a conceptual vision of rehabilitation based on moral treatment principles. They were persons discontented with the growing movement of medicine toward an exclusively biomedical orientation predicated on reductionism. Their vision of rehabilitation incorporated the ideas that the patient in rehabilitation had to be an active agent participating in normal life as much as possible and working with rehabilitation personnel to reinstate a satisfying and productive lifestyle. This conceptual orientation was reflected, for example, in the design and fabrication of prosthetic devices and special equipment. The person's desires, anticipated lifestyle, life roles and other personal and cultural traits determined what equipment was chosen and used (Dunton, 1919). Many of the early rehabilitation settings included extensive workshops wherein patients engaged in contemporary crafts, leisure pursuits, and pre-vocational activities designed to allow the individual to participate in the tasks of living, producing and enjoying. Such an orientation, however, was increasingly distant

describes entities and relationships recognizable in a variety of phenomena across several disciplines. Boulding (1968) describes General Systems Theory as providing a skeleton or framework upon which disciplines may place their specific substantive concepts and theories. Thus, the language of systems is not specific to phenomena per se, but to levels of complexity and types of relationships that may be observed in phenomena.

I will focus on two important conceptual themes of General Systems Theory, hierarchy and open systems. After a brief discussion, I will demonstrate their use as a framework for one current rehabilitation model.

Hierarchy. The concept of hierarchy is directed at the recognition of levels of complexity in nature and to description of laws governing each level and the relationships between levels. Several hierarchical schemas have been proposed by such writers as Boulding (1908), Brody (1973), von Bertalanffy (1968), and Feibleman (1969).

The concept of hierarchy refers to the recognition that not all systems or all phenomena within a given system are of the same level of complexity. Recall that reductionism ultimately saw all phenomena as parallel--that is, ultimately reducible to the cause and effect chains between similar elementary constituents. The concept of hierarchy argues that such reduction of phenomena is not conceptually correct, but rather that different levels of complexity in nature must be identified. Each higher level emerges out of and depends on the prior existence of a simpler level, but it exhibits a coherence and lawfulness that is not reducible to the lower level. Weiss (1968) made the observation, $\{\Sigma V \infty << \Sigma(V_1, V_2, \ldots V_n)\}$ in relationship to the living cell. It signifies that the sum of observed variances of the cell as a whole will always be less than the sum of possible variances of the constituents of the cell. Put another way, the chemical activity of the cell is disciplined; it will represent fewer degrees of freedom than the chemical activity found when the equivalent chemical constituents of a cell are combined. This he attributes to the fact that occurrences in the inanimate constituents of a cell represent a level of complexity explained by the periodic table, whereas the occurrences in the cell are more than what goes on among the constituents (not in a quantitative, but in a qualitative sense). There is a lawfulness inherent in the living cell which is not reducible to the chemical laws governing how various elements will interact in a mixture. The cell does rely on and build upon the laws of chemistry or the laws governing how elements will interact, but it adds to those laws, new principles governing a new emergent order or new level of complexity.

Another example of emergent phenomena is the way in which human cognitions and emotions flow out of, yet depend on the operations of neurophysiological processes of the brain. Cognition and affect are emergent phenomena which illustrate a complexity and lawfulness beyond what can be determined by or predicted from the actions of neuronal firings. A third example of this process is the emergence of culture or society from the interaction of human beings. Society is not reducible to the interactions and social thoughts of its members. It exists continuously with a manifest order as new members are inducted and old ones leave the social system. Were this not the case, we could reduce the study of sociology to the study of psychology and eliminate the latter.

In sum, the concept of hierarchy begins with the recognition that different irreducible levels of complexity exist in nature. Each higher level emerges from and builds on the lower level and it manifests a new order, an emergent coherence and lawfulness not predictable from the lawfulness of lower order phenomena.

Several relationships between phenomena at different levels in a system have been described in the literature. Three of these laws, commanding, constraining and resonating, are most salient to the present discussion.

Commanding refers to the relationship of a higher level phenomena to a lower level phenomena in a system: the higher level can give instructions to the lower levels for how to use its degrees of freedom. Consider the example of willing to wriggle one's little finger. A number of movements are possible for this fifth digit. One may extend and flex, abduct and adduct. Choosing to wriggle the little finger (i.e. flexing and extending it in alternation) results in the use of 2 of four possible movements. In this example, mental volitional events give commands to neurophysiological phenomena. Sperry (1970) refers to this process of conscious causation of neurophysiological events as "supervening." The nervous sytem in turn commands a particular set of muscles to act over certain joints and thus "commands" a series of movement.

Constraining refers to the relationship of lower to higher levels. Recall that higher levels rely on and build upon the lower levels for their operations. Thus one cannot will to move the little finger if a lower subsystem is disordered. A frozen arthritic joint or a severed peripheral nerve may constrain the volitional element.

Resonating refers to how events at any one level of a hierarchy reverberate throughout the system both upwards and downwards. Let us take, for example, a cerebrovascular accident. Because the brain governs signals across the peripheral nerves to the muscles, disorganization at the brain level leads to disorganization at the lower levels. Muscle flaccidity or spasticity may occur along with paralysis and sensory loss. In time this may result in structural damage such as a subluxation of the glenohumeral joint and deformity of the hand. At the same time, the brain damage reverberates upward through the system. It may constrain symbolic functions leading to a language disturbance such as receptive aphasia and it may affect mood. Finally, it will resonate through the social system, perhaps removing the individual from his or her social role and casting him or her into a deviant or impaired role. Thus, in a hierarchical system, disturbances at any one level are recognized to resonate throughout the other levels.

It is easier to predict how the resonation

will occur downward in the system than upward. For example, one can predict what motor and sensory loss will occur when a complete C_8 - T_1 lesion of the spinal cord occurs, but one cannot predict whether the lesion will prevent the person from fulfilling his social role. If he is a truck driver, surely it will, if he is a college professor it is less likely. Thus, higher levels have the ability to either intensify or palliate the effects of disturbances at a lower level. If, for instance, society values its handicapped members and perceives an obligation to provide meaningful roles for participation in social life, then the effects of disability are minimized. If society stigmatizes and views its handicapped members as social baggage, then the effects of the disability are exaggerated. Similarly, if a patient becomes emotionally despondent over the loss of function of the lower extremities, the patient will ultimately be more disabled than another who has lost function of all four extremities, but who has a strong will to overcome the disability and function in spite of it. As these examples illustrate, the concept of hierarchy is very relevant to our understanding of the process of adaptation in persons with a physical impairment.

Open systems. The second set of concepts is open systems, which refers specifically to the properties exhibited by animate, or living, phenomena. The open system is a system which maintains and changes itself through the cycle of interaction with the environment. The cycle involves four phases. Intake is the importation of information and energy from the environment. Throughput is the transformation of that information and energy for use by the system and the transformation of the system itself to accommodate the information or energy. Output is the action of the system, and feedback is the information generated about the processes and consequences of output. This cycle is conceptualized as self-reinforcing and it results in directional change in a system. Since the system's action is a link in the cycle, open systems are recognized as self-driving, self-maintaining and self-transforming. Because of the intense interaction with the environment, open systems are heavily influenced by the information and energy available in the environment. They are not passive pawns of the environment, but their fate is tied to environmental characteristics.

The concept of open systems provides a conceptualization for self-maintenance and self change which differs from that of the closed system (i.e., the machine which, when disrupted, requires an external repairman). Recognizing that humans are open systems, for instance, requires recognition that what one does will influence the transformation of self. For example, surgical intervention and medication with antibiotics can help insure the survival of a patient after traumatic spinal cord injury. However, what the person does in the course of therapy--that is, how much he or she exercises remaining musculature, what skills of self-care and problem solving he or she generates, how he or she interacts with and learns to manage the newly transformed social milieu will ultimately make the difference in survival and life satisfaction. No amount of repair work by a medical practitioner can eliminate the need for the patient to self-transform through what he does. Similarly, the fate of the patient will depend in large measure on conditions in the environment. These conditions will include architectural barriers, mechanical and electronic extensions of function, family and neighborhood support and political policy concerning funding for training and employment of such persons.

A model

Building on the aforementioned concepts General Systems Theory, I and a number of colleagues have been involved in the development of a conceptual model for our particular area of practice in rehabilitation, namely, occupational therapy (Kielhofner & Burke, 1980). Since the model is oriented to the concerns and the self-imposed boundaries of one professional group, it will not speak to all issues in rehabilitation. It might be best considered as a rough prototype for a general rehabilitation paradigm or an example of the types of operational models which might be integrated eventually into a global rehabilitation paradigm. It should be noted that since the model is oriented to everyday functional concerns in productive and social activities, it may be relevant to the role of engineering in facilitating human adaptation.

This model is labelled the model of human occupation as it speaks to that area of human functioning of concern to occupational therapists. The model is based on the broad concept of adaptation originally articulated by Dubos (1959) and recently suggested by Levy (1983) as an appropriate concept for rehabilitation in general. The model also assumes that many facets of human adaptation can be identified and addressed in rehabilitation (examples being spiritual or existential adaptation, biological adaptation, sexual adaptation, interpersonal adaptation and the like). The model also assumes that occupational therapists serve only one facet of human adaptation, namely, occupational adaptation. They do so as part of a rehabilitation team whose total efforts should address the total adaptation needs of the rehabilitant.

Occupation is defined as a particular sphere of human behavior which is motivated by a need for exploration and mastery in life and which manifests itself in everyday behaviors of work, play and self care. The model of human occupation is thus oriented to providing a way of conceptualizing the motives for, the organization of, and the production of work, play and self-care activities.

This model conceptualizes human beings as open systems exhibiting output or behavior (which in this model is work, play and self-care behavior), generating feedback concerning that behavior, and taking in relevant information. This cycle maintains and transforms the capacity for work, play and self-care. Three hierarchical subsystems are recognized within the human system: volition, habituation and performance. The performance subsystem is the lowest and most basic

subsystem and it is responsible for the production of behavior. This subsystem consists of skills and their constituents. The constituents are musculoskeletal, neurological and symbolic. The types of skills are perceptual-motor (skills for dealing with self and objects in the world), process (skills for dealing with events by planning or problem-solving), and communication/interaction (skills for cooperating and competing in playful and productive activities).

The second subsystem is habituation and its responsibility is for the organization of behavior into routines or patterns. This subsystem is composed of habits and roles. Habits pattern the skills of the performance subsystem into routines organized to the usual contingencies of time, place and people in the environment. Roles place the individual in the social structure and convey both statuses and expectations to the role incumbent.

The highest volition subsystem governs others through its decision-making capacity. Volition consists of an energy source and three symbolic components. The energy source is the universal human urge to explore and master. The symbols are persons' internalized experiences of themselves as actors in the world. These internal representations shape how the person will act on the urge to explore and master. They include three collections of symbols: personal causation, interests and values. Personal causation refers to the individual's recognition of personal efficacy in action. It includes beliefs in internal versus external control of life events, beliefs concerning the possession of skill and the efficacy of skill and finally anticipations of success and failure in the future. Interests are images of one's experience of pleasure in action. The disorientation of interests shapes behavioral choices toward a pattern of activities that one finds enjoyable and satisfying. Values are persons' culturally-acquired perceptions and convictions concerning what they should do. Values that pertain to occupation include a person's orientation to time and how it should be used, occupational goals, standards of personal performance and the meaning of various activities.

Together, one's sense of personal causation, values and interests shape how an urge to explore and master will be enacted as everyday occupational behavior. Volitional choices lead to the development of skills and habits and to role taking. In this way volition governs the other subsystems. Lower subsystems can also constrain the higher. The status or limitations of skills, for instance, can delimit which roles a person may take on or which values can be actualized.

As an open system, humans are shaped by and adapt to properties of the environment. The environment is conceptualized as representing four levels with which persons interact in their occupations; they are objects, tasks, social systems and culture (Barris, Levine, and Neville, in press).

The model serves as both a framework for understanding normal human functioning in everyday occupation and for conceptualizing problems that arise in association with disability. Let me briefly illustrate the latter. Consider the case of an acute traumatic disability such as a spinal cord injury or head trauma. In such cases the neurological and/or musculoskeletal constituent of the performance subsystem is affected. This results in a loss of ability to perform perceptual motor skills. Loss of sensory and motor capacity requires an increase in process skills--that is, conscious planning and problem-solving. The stigmatizing effects of the disability may make communication and interaction with others difficult and radically different. Disruption of the performance subsystem demands changes in daily habits. The newly disabled person must construct a new sense of the taken-for-granted routines; even such fundamental dimensions of habit as time and space become newly objectified, demanding a new orientation and a new set of routines (Paap, 1973). Physically disabled persons may further find themselves unable to enact their familiar roles. They may internalize an impaired, deviant role. These persons will likely have difficulty pursuing premorbid interests and values because of the limitations imposed by the new disability. Their sense of personal causation is greatly threatened as losses of physical and sensory capacity and the ability to enact skilled performance is devastated through the disability.

In addition to the changes within the system, the system's relationship to the environment is vastly altered. Objects which were previously manipulated with ease now become formidable and unwieldy. Life tasks all take on a new character; simple behavior such as dressing, driving or work performance may be extremely difficult or impossible. Previously disabled persons find themselves in a world of new objects and tasks which are part of the technology of living as disabled persons. They may also find themselves newly prevented by physical and social barriers from access to social systems. And they will have to deal with new social systems beginning with the hospital and rehabilitation facility and extending into the community after rehabilitation. Finally, cultural values concerning independence, physical beauty and prowess that formerly may have been a source of positive self-evaluation may now become cause for self-deprecation.

The resonation of disability throughout the system and its relationships to the environment also affect the open system cycle resulting in a reduction of cessation of output, consequent elimination of positive feedback and isolation of the system from information and support in the environment. The cessation of the open system cycle is the most critical since the open system depends on this ongoing cycle for self-maintenance and change.

The model thus orients us toward the broad implications of a neuromuscular disorder and its resonation throughout the system, the environment and the open system cycle. From such a vantage point it is possible to recognize that any efforts to assist such persons in the process of rehabilitation cannot afford to be fragmented or focused on only one aspect of the problem. Biomechanics may tell us something about what equipment may enhance performance capacity, but unless the individual's volition remains intact,

he or she will simply not make use of such devices. Unless the social system responds to the disabled individual's desire to be productive, no amount of technological assistance will effect an adaptive lifestyle. Thus we can see that technological, biological, psychological and social actions are all needed in concert to affect successful rehabilitation.

Beyond these implications, two other important lessons are drawn from this model. First, intervention cannot assume the human being is a deficit machine which can be repaired and thus returned to function. At the very least rehabilitative efforts must recognize disability as extending to what the person is able to do and what the environment allows him or her to do. Second, any effective change we seek for the individual must be self-initiated volitional change that results in an ongoing adaptive open system cycle. Such change requires that we focus our attention to the characteristics of the physical and social environment and that we recognize the individual's goals and genuine participation as central to the rehabilitation process--both old themes in rehabilitation. We cannot modify internal properties of the system by external manipulation, or through intrusive procedures as in the medical mode. We cannot surgically remove and replace roles and values. Rather the open system conceptualization requires that we find ways of supporting and eliciting the participation of the individual reactivating the open system cycle to allow self-change and self-maintenance. Such a conceptualization thus calls us to view our roles in rehabilitation less as healers and more as partners in enabling persons to construct or reconstruct the totality of their lives. The person and what the person wants to do and does becomes the focus of intervention.

If models such as the one I have briefly presented emerge within the field of rehabilitation and engender a like paradigm based on system thinking, it is possible for rehabilitation to achieve status as a viable and important branch of health care, emancipated from the reductionism of the medical model and grounded in a humane and socially viable system of care.

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TRANSCENDENCE
TOWARDS AN ETHICS OF REHABILITATION

David J. Roy
Clinical Research Institute of Montreal - Montreal, Quebec H2W 1R7

ABSTRACT - This paper reviews some of the considerations emerging from the natural sciences and philosophy that will contribute to the foundations of an ethics of rehabilitation.

RÉSUMÉ - Ce texte passe en revue quelques idées qui émanent des sciences naturelles et de la philosophie et qui jouent un rôle dans les fondements d'une éthique de la réadaptation.

MY CONTEXT: OPENING QUOTATIONS

"In conventional medical diagnosis and clinical care, the drama of the emergency, of massive intervention through surgery, and a rapid changes in patients' condition compel attention. By contrast, treatment and rehabilitation in response to chronic disabling conditions is likely to be a long, melancholy process dealing with the reality of permanent impairment while stressing capacity. No wonder, then, that rehabilitation has been the impoverished and distant relative of clinical care."[1]

"What, with so different a past has caused the great nothing with which philosophy today responds to one of its oldest questions -- The question of how we ought to live?"[2]

MY LITERARY FORM: AN ESSAY

From the very start, you should know what I am trying to do, even if I myself will not know this in any adequate way until I've actually done it. That is the meaning of an essay. I'm setting about to write an essay on the ethics of rehabilitation.

An essay. There is an undertone of incompleteness, of the need to start over and over again. Indeed, each part of this essay is little more than a preface, the mere introduction of directions of thought. They have to be pursued and then brought together to move towards an understanding of human difference and the emergence of an ethics of rehabilitation.

The essay moves forward along many paths linked by "the dynamic structure of rational self-consciousness", what B. Lonergan calls "the root of ethics". I trace the ways we have followed in pursuing our understanding of nature and seek clues about how we should understand ourselves and act towards one another, in short, of how we should live.

The orientation of the essay is hardly original. It takes up a notion of ancient Greek thought. Nature for the Greeks was a dynamic concept, an order of forms governed by an immanent purpose, a "logos". This "logos" was the source of meaning, meaning the source of norms. So ethics, in this vein of thought, will not be unlike Aristotle's famous description of art as an imitation of nature. Imitation, though, has little to do with static copying, for ethics deals not with the world as it is, but with the world as it could and should be.

And, how is that? Certainly more unexpected, infinitely more imaginative and irregular, strikingly more evolving, than static classical and utilitarian views of nature, human or otherwise, would allow.

Blaise Pascal and Benoit Mandelbrot give this essay its spirit. Pascal said that the human imagination tires in its run to keep step with the infinite inventiveness of nature. So does ethics. It lags behind, so far behind, the kinds of human world nature suggests we could create. Mandelbrot, sensitive and attentive to the infinite irregularity of nature, had to create a new geometry of nature, "fractal geometry", to investigate and represent the morphology of the "amorphous". We need a new ethics of rehabilitation to enhance the self-representation of those often too disabled to be seen otherwise than in the light of their possible adaptation to the governing ethos of a utilitarian society.

A number of fundamental notions and insights, at first sight bearing only the most distant relation to the human challenge of permanent impairment, form a heuristic framework for the ethics of rehabilitation. Each of these notions bears a relation to the others. They have to be read together.

1. Evolution Away From Chaos

Two Americans of Chinese origin, the physicists T.D. Lee and C.N. Yang, won the Nobel Prize for Physics for the year 1957 for their discovery of the violation of the principle of conservation of parity. In 1956 Dr. Wu and her colleagues put these ideas to an experimental test. She placed cobalt in a magnetic field and thereby assured that all the axes of the cobalt nuclei were parallel to one another in space. The key question? Would cobalt during radioactive decay emit equal numbers of electrons on either side of a plane perpendicular to the orientation of the axes? In fact, they did not. Nearly all the electrons were emitted to one side of this plane.

Jean E. Charon, a physisist, interprets this phenomenon as follows. Since the flow of electrons to one side could not be due to differences in the structure of space, could not be due to the anisotropy of space, "we are forced once more to conclude that there is an anisotropy of time which allows cobalt to distinguish right from left. Cobalt is 'aware' of a future different from its past, and it uses this fact in making a spatial distinction between its right and its left. It is capable of making a choice between these two directions."[3]

Some may ask, what is so important about cobalt? The importance becomes striking when we realize that "in physics", a phenomenon can never be dissociated from all the other phenomena which surround it. Thus it is not only the future of cobalt, the subject of the experiment, which will be realized; the future of the whole universe is bound up with that of cobalt. In preferring left to right, the cobalt is proving that there exists a future for the whole universe which is different from the past of the whole universe. Moreover, this implies that the universe transforms itself, or evolves. In this simple experiment of the dissymmetry of cobalt, we have laid hold of an irrefutable proof that there is an evolutionary ladder, so to speak, on a universal scale."[4]

The evolution of the universe, if we follow Charon's interpretation, pursues a direction away from its original state, through differentiation, towards higher integration. This evolutionary process is linear, not cyclical. Something new emerges, not just Nietzsche's eternal return of the same. Moreover, an order is emerging through this process, not just the play of chance.

One of Charon's closing remarks is of the greatest interest. He points out that physicists do not like to speak of a wave of the future in their descriptions of the present state of the universe because "this would amount to saying that a future state can in some way intervene to guide phenomena situated in the present". Some view such an idea as metaphysical mysticism. Others recall the Aristotelian and Thomistic principle of finality. In any event, cosmologists have now openly returned to a form of this principle and of explanation by finality in their attempts to account for the starting conditions of the universe.

2. The Anthropic Principle

John A. Wheeler of the University of Texas at Austin has offered the perhaps strongest interpretation of the anthropic principle. This interpretation would hold that "the observer is as essential to the creation of the universe as the universe is to the creation of the observer."[5]

The anthropic principle is used in cosmology because the usual deductive method does not work when the question to be answered asks about the initial conditions of the universe. A deductive theory needs to have the initial conditions of a physical system and the laws pertaining to it specified before it can proceed to predict a later state of that system. But the initial conditions of the universe are unknown and we are uncertain about the laws that held under those conditions. The anthropic principle starts with the existence of intelligent life and argues that this presence places constraints on the many ways the universe could have begun and on the kinds of laws that governed its development. The principle states: possible initial conditions and pathways of development do not in fact apply to our universe because, if they did, we, as intelligent observers, would not be here today.

The anthropic principle essentially states that the existence of man can be used as norm to select one among many possible explanations of how the universe has evolved. For example, Robert H. Dicke of Princeton has used the principle to argue that the Hubble age of the universe could not, given the existence of man, have a value much different than it presently has. The Hubble age has to harmonize with the conditions of the universe necessary for the appearance and maintenance of human life. If the age of the universe were much less than the Hubble age, the time would not have been sufficient to permit the formation of elements heavier than hydrogen. Without carbon, for instance, people would not exist, at least not as they now exist on this planet. If the age of the universe were much longer than the Hubble age, stars with planets capable of supporting intelligent life would have died out. R. Dicke's analysis shows that the Hubble age of the universe is not arbitrary. The present existence of man is the key principle of his analysis. He "cites a present condition (man's existence) as the explanation of a phenomenon grounded in the past (the age of the universe)."[6]

C. B. Collins and Steven W. Hawking employ the anthropic principle in a similar way to

explain the simultaneous features of large-scale isotropy of space and small-scale inhomogeneities, such as galaxies, in the present structure of the universe. These features can obtain only if the recessional velocity of matter is exactly equal to the escape velocity. This means that "the observed universe is a highly privileged one indeed; where the recessional velocity has one arbitrary value out of an infinite range of possibilities."[7] Collins and Hawkins conclude that the structure of the observed universe must be "a consequence of our existence".[8]

The new astronomy of Copernicus and Galileo displaced the earth from the center of the universe to the planetary periphery of one star, our sun, in the universe. Many believed this meant that man was losing his central and privileged place in the universe. Our most recent cosmology, utilizing the anthropic principle, accords to manthe infinitely greater privilege of being the raison d'être of the presently observed structure of the universe.

3. Wholeness and the Implicate Order

How can statements, such as Charon's proposition about the future of the universe being bound up with that of cobalt, be taken seriously? It is indeed difficult to make sense of such ideas as long as we continue to perceive and think about the world in the terms of a mechanistic world order. An order gives a model of how things are related to each other. A mechanistic order essentially presents things as existing independently of each other, as parts connected only by external relationships.

Relativity theory and quantum theory presented basic challenges to the standing assumption that mechanistic order adequately accounts for the way things are related in the universe. For example, fields not particles are the basic reality in Einstein's attempt to work out a description of the universe in terms of a unified field theory. Particles become singularities, regions of field intensity and the fields of one singularity merge with those of another as distance from each singularity increases. David Bohm draws the following conclusion about this way of viewing the universe: "Thus, the classical idea of the separability of the world into distinct but interacting parts is no longer valid or relevant. Rather, we have to regard the universe as an undivided and unbroken whole. Division into particles, or into particles and fields, is only a crude abstraction and approximation. Thus, we come to an order that is radically different from that of Galileo and Newton -- the order of undivided wholeness."[9]

Quantum theory challenges mechanistic world views even more radically than relativity theory does. Nevertheless, quantum theory supports the notion of undivided wholeness. It is widely known that the context of quantum theory demands a new kind of description that does not permit a separation of the observed object and the observing instrument. The actual state of a physical system in quantum theory cannot be accounted for without simultaneously taking into account the whole surrounding matrix of experimental conditions that actualize this state, one among many potential states covered by the wave function.

This situation leads David Bohm to conclude: "A centrally relevant change in descriptive order required in the quantum theory is thus the dropping of the notion of analysis of the world into relatively autonomous parts, separately existent but in interaction. Rather, the primary emphasis is now on undivided wholeness, in which the observing instrument is not separable from what is observed."[10]

Quantum theory and relativity theory, while both indicating the need to go beyond a mechanistic view of the world, also suggest the need to move towards a higher theory to accomodate, if for no other reason, the contradictions each theory poses for the other. D. Bohm has described how "relativity theory requires continuity, strict causality (or determinism) and locality. On the other hand, quantum theory requires non-continuity, non-causality, and non-locality".[11] Though one may not understand all of the details of this analysis, one can grasp that science today is in a position similar to that of Galileo when he began his investigations. Like Galileo, "We have thus yet to perceive a new order". This grasp of a new order "may ultimately carry us as far beyond quantum theory and relativity as Newton's ideas went beyond those of Copernicus".[12]

David Bohm believes that we are on the road to discovering a new order in the universe. He uses the term implicate order to indicate this new way of perceiving how things are related. The key idea of implicate order is "that everything is enfolded into everything. This contrasts with the explicate order now dominant in physics in which things are unfolded in the sense that each thing lies only in its own particular region of space (and time) and outside the regions belonging to other things."[13] This new order would apply to both living and non-living matter and offer a framework to understand the relationship of matter to consciousness.

4. The Principle of Self-Representation

The role of color in the worlds of the stickleback, the bee, the butterfly, and the parrot, in general, of fish, birds, and insects reveals principles of nature that have far-reaching human significance. The principle of self-representation or self-display, what Adolf Portmann calls "selfstdarstelling", is one of these. It takes us beyond "the neo-Darwinian reduction of all organic phenomena to their functions."[14]

Portmann's analysis leads to the conclusion that the marvelous displays of splendid colors in fish, insects, and birds can be only partially explained by principles of functional utility of natural selection. He needs to distinguish "unaddressed" from "addressed" phenomena to account for "color broadcasts" in the bodies of living beings that are "directed to no seeing eyes."[15]

The unaddressed color broadcasts transcend the explanatory reach of the principle of functional utility and indicate "that the concept of utilitarian adaptation has been overestimated in our assessment of natural forms"[16] This transcendence creates space for the emergence of another role for these "useless" patterns of color, the role of self-representation or self-display, an expression that functions not as a signal but seems "to be simply an end in itself."[17]

The principle of self-representation is primary. It requires structures in living creatures as complexe as those needed for functional organs, in particular, for the organs of sight that respond to color in a functional, utilitarian adaptive way. "Thus in living creatures that which is to see and that which is to be seen are objects of similarly intricate hereditary preparation. This insight is beginning to prepare the way for quite comprehensive transformations in our image of nature."[18]

Self-representation demands a price. It is costly in time and energy. "The biochemical expenditure, the number of specific enzymes and reactions which serve the self-representation of living things, is tremendous, and equally large is the number of physical structures whose ultimate function is the production of color."[19]

A final point is enormously important. It emphasizes light as the condition for the exercise of the role of self-representation. "The distribution of the living forms tells us that the lightless places in which living things are found are secondary zones of life, that the largest wealth of forms has evolved in the illuminated realm, and that from a very early level of life onward the light-filled zones made possible the highest development of the organisms. Illumination as a primary fact of the original medium of life stands in mysterious and strict relation to the phenomenon of 'appearance': we acknowledge self-representation of the species in the realm of light as one of the meanings of organic form -- as a meaning which points beyond that of simple preservation."[20]

This analysis indeed embodies a quite comprehensive transformation in our view of nature. It takes us beyond a reduction of living forms to utilitarian functions.

These living forms are there for their own sake. Their very appearance is the sufficient reason for complexities of structure and expenditures of energy that serve no identifiable utilitarian function. Centricity and self-display are two of Portmann's prime characteristics of living creatures. "Living things as they display themselves to the world and as they carry on, out of their own centered existence, ordered transactions with their environments, are significant in themselves. The criterion of self-maintenance, important though it is, must be counted as a third character in subordination to the other two."[21]

5. Ethics In Crisis

Ethics reveals and tests the anthropology in which it is grounded and out of which it arises. But ethics, in this period of our Western culture, is in a state of crisis. We are in a period of transition marked by confusion and uncertainty. Traditional ethics is at a turning point as it faces the need for a radical transformation. Traditional ethics "had these interconnected tacit premises in common: that the human condition, determined by the nature of man and the nature of things, was given once and for all; that the human good on that basis was readily determinable; and that the range of human action and therefore responsibility was narrowly circumscribed."[22] This condition of ethics has changed profoundly.

If modern science and technology, biomedical science and technology in particular, have "introduced actions of such novel scale, objects and consequences that the framework of former ethics can no longer contain them," how do we set about constructing the framework of a new ethics?

The very notion of a normative ethics is itself in question. There is an epistemological dimension to the contemporary crisis of ethics. At the very moment when a global ethics appears as an increasingly urgent necessity, a normative ethics of any sort appears to be impossible. Rational justification of norms would have to be a necessary, if not sufficient, condition for transnational and transcultural consensus. However, the notion of value-judgments as opposed to subjective and arbitrary value-preferences is foreign to the currently dominant notion of scientific objectivity. A rational, objective, and intersubjectively valid justification of norms presumes a rationally justifiable hierarchy of values. Both seem to be in principle unattainable on the basis of the currently dominant concept of objectivity. On this basis, ethical norms are reached by arbitrary and subjective choice, not by rational argument. Working towards a normative ethics, let alone a globally normative ethics, means parting ways with the assumption that "scientific rationality, in the sense of the logic of science (i.e., logical inferences plus observation), in fact exhausts the whole of human rationality, so that beyond its

limits only the irrationality of arbitrary decision can exist."[23]

The foundations of contemporary ethics have crumbled. We repeatedly find it difficult, at times impossible, to distinguish right from wrong and, indeed, on matters that we know are critical for the fate of individuals and communities of human beings. The most perspicacious of minds know what it means today to be buffeted by waves of uncertainty; know the tearing experience of trying to simultaneously protect high values that are in conflict. We have either lost the reference system that would permit us to decide with solidarity and moral assurance which value may or has to be sacrificed or we have created a world that continually engenders tragedies, situations in which people of good will are forced to practice moral triage.

Ethics is in a foundational crisis because earlier intelligible orders that exercised sway over the mind and created a community of moral meaning have disintegrated or are in the process of doing so. A new intelligible order, a new unified moral field theory has not arrived. A new and vigorous voluntarism is arising within the space created by the disappearance of morally normative intelligible orders. Choice is the norm and choice becomes "an act of will responsible to nothing beyond itself."[24] If the moral boundaries of an intelligible order for human living no longer hold, there is no conceivable constraint on what we shall try, no imaginable perimeter at which we shall stop, for human desire per se has no internal limits. Today's crisis, as one interpretation would propose, emerges from the combination of an "anarchy of human choosing with the apocalyptic power of contemporary man -- the combination of near-omnipotence with near-emptiness."[25]

The task of ethics is to illuminate the conditions for consistency between knowing and doing. However both theory and practice are in a constant state of flux. Is it at all possible to discover a solid foundation for ethics in a cultural period marked by radical innovation and the impermanence of yesterday's ideas? Hans Jonas offers an approach towards the foundation of ethics when he proposes: "Only an ethics which is grounded in the breadth of being, not merely in the singularity or oddness of man, can have significance; and whether he has it we must learn from the interpretation of reality as a whole. But even without any such claim of trans-human significance for human conduct, an ethics no longer founded on divine authority must be founded on a principle discoverable in the nature of things, lest it fall victim to subjectivism or other forms of relativity."[26]

A principle in the nature of things as a foundation for ethics? Is the idea not dawning upon us that there is nothing in nature that, in principle, cannot be changed and refashioned to match the purposes we adopt as our factual norms of the moment? How are we to think of nature? As the source of materials and targets for human creativity? As a normative pattern of terminal structures that, in the long run, will respond with total collapse to any prolonged course, if not programme, of human manipulation? Nature cannot be a principle or foundation for ethics if, in fact, "anything can be done with nature without violating its integrity, for there is no integrity to be violated in a nature conceived in the terms of natural science alone."[27]

6. Towards the Foundation of Ethics

Jonas is seeking the possible foundation of ethics. He comes close with his recognition that ethics must be founded in a principle discoverable in the nature of things. He begins to lose his way when he overlooks the fact that the principle of man's singularity in the universe is also the principle of his universality.

Even wide ranging philosophies of mind, organism, and nature will not, as a complex set of propositions, serve as the foundation of ethics. If ethics deals with the consistency between knowing and doing, then the foundation of ethics will have to be a principle which is discoverable as a dynamic function that delivers this consistency.

This is what Lonergan has understood with his position that "the root of ethics, as the root of metaphysics, lies neither in sentences nor in propositions nor in judgments but in the dynamic structure of rational self-consciousness. Because that structure is latent and operative in everyone's choosing, it is universal on the side of the subject; because that structure can be dodged, it grounds a dialectical criticism of subjects. Again, because that structure is recurrent in every act of choice, it is universal on the side of the object; and because its universality consists its universality consists not in abstraction but in inevitable recurrence, it also is concrete."[28]

On this view of things, the real principles of ethical precepts and codes "are not propositions or judgments but existing persons." Existing persons live in community. "Community is not just an aggregate of individuals within a frontier, for that overlooks its formal constituent, which is common meaning... The genesis of common meaning is an on-going process of communication, of people coming to share the same cognitive, constitutive, and effective meanings."[29]

This on-going process of communication defines Karl Otto Apel's "Kommunikationsgemeinschaft" and motivates his turn to "Dialog als Methode".

If persons are the root of ethics, then an orientation and emancipation of persons is re-

quired that permits performance to match the reach of aspiration. The problem of liberation "lies in an incapacity for sustained development."[30] Sustaining development is a process of transcendence. Transcendence occurs with the recurrence of the dynamic structure expressed in the transcendented imperatives: be attentive, be intelligent, be reflective, be responsible.

The problem of liberation occurs when this structure fails to recur. On one level the problem appears as a "succession of ever less comprehensive viewpoints."[31] On this level the solution "has to be the attainment of a higher viewpoint."[32] On another level the problem appears as a break-down of the process of on-going communication. How could it be otherwise? On the level of the mind, transcendence occurs when an unconditioned is grasped. On the level of human living transcendence occurs when an unconditioned is realized, made real. Human communication reaches its full scope in such an achievement, the achievement of unconditioned acceptance and unconditioned gift. However, when one can or will no longer grasp the unconditional in the level of the mind, how can one achieve the unconditional in human living? So on this level the solution to the problem of liberation "has to be a still higher integration of human living."[33]

The decisive insight, however, defines the order governing higher viewpoint and higher integration within the solution to the problem of liberation: "The needed higher viewpoint is a concrete possibility only as a consequence of an actual higher integration."[34] How are we going to achieve that?

7. Toward An Ethics of Rehabilitation

Foundational concepts and statements express the basic assumptions and positions, often critically unexamined, that govern more specific norms, criteria, standards, guidelines, and policies used to resolve value conflicts as well as to direct decisions that promote some values and sacrifice others.

This unfinished essay has explored several pathways of the natural sciences and philosophy on the premise that both reveal insights belonging to the foundations of an ethics of rehabilitation. To lay the foundations would mean synthesizing these elements along with other insights that have not even been considered here. Obviously, this is a task for another day.

However, foundational statements are meant to be heuristic, to suggest solutions to real problems and the restructuring of false ones. I close with several of the suggestions implied in the foundational statements presented in this essay. These suggestions, in turn, contain more concrete implications for shaping a community's policies and behavior towards those who suffer more or less profound disability and impairment.

- Transcendence and emancipation, not utilitarian adaptation, define a basic goal of rehabilitation services. This means investing energy and developing the complex social structures required to permit the self-representation of the disabled.

- Integration of the disabled into the community, not selective survival of the utilitarian fittest, defines a condition necessary for the transcendent emergence of the disabled and handicapped into the primary zones of life. Living forms need light to achieve their highest development. For their highest development, human beings need the light of social presence.

- The transformation of the community is as essential to the transcendence of the disabled as the transcendence of the disabled is to the transformation of the community. The principles of undivided wholeness and implicate order imply that the being of a society is bound to the becoming of its disabled.

- The universe evolves away from chaos towards productive integration. That is the deeper meaning of theoretical contemporary discussion about models of rehabilitation. The question of a needed higher systems viewpoint is simultaneously a moral quest for a real integration of rehabilitation services and a real integration of the disabled into the community.

If the observed universe, according to the anthropic principle, is a consequence of our existence as human bings, is it illusory to hope that our society will be seen in the future as a zone of light for those who, left to the forces of utilitarian selection, would atrophy in the secondary zone of social darkness?

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DISINCENTIVES TO INDEPENDENT LIVING

Irving Kenneth Zola
Brandeis University, Waltham, Massachusetts 02254, USA

ABSTRACT - The slow rehabilitation into mainstream USA of Americans with a disability/chronic disease can be attributed to certain contradictory American values, over-reliance on technology, and a reluctance to admit the patient-consumer as a partner in his own habilitation/rehabilitation.

RÉSUMÉ - La très lente réadaptation aux Etats-Unis de ces Américains qui souffrent d'incapacité motrice ou de maladie chronique s'explique par un certain nombre de valeurs américaines contradictoires: confiance sans borne dans la technologie et réticence à considérer le malade-client comme un partenaire de son propre traitement d'adaptation ou de réadaptation.

INTRODUCTION

In recent years we have heard a great deal about disincentives.[2] This has called attention to features in our rehab approach which work to the disadvantage of our clients. It is an important move both politically and socially. For it shifts significantly our analysis onto the very system which is supposed to serve that client.

Historically such a shift follows a pattern. In the late 1950's and early 1960's there was a similar refocusing in the study of a wide range of social problems.[1] Then too questions were raised about the role of treatment systems in maintaining, if not creating, the very problems they were supposed to solve. It is, at very least, 'a tribute' to the strength of the medical model that it has taken nearly two decades for this critical approach to filter first into the field of medicine[5] and then into rehabilitation.

The resistance to such a refocusing goes deep. The first attempts to assure physical accessibility to those with disabilities are particularly illustrative. Though financial issues were often paramount in the retrofit of existing facilities, it became clear that where new buildings were concerned, financial and architectural issues were but a smokescreen. I remember attending an architectural class where a student objected to the ramping of a facility on aesthetic grounds. When a consumer-participant in the class objected, the student argued that this was a matter better left to experts. So too have I far too often heard consumers' objections to their treatment brushed aside as being a 'technical' problem and, as such, better left to the technical experts.

In the rest of this paper I want to trace out the implications and thus the disincentives that come about when we neglect the consumers' input into "technical problems."

INDEPENDENCE - WHOSE VIEW?

Independence and self reliance are very strongly held American values. American dependence on foreign energy sources need only be mentioned and the public rises in indignation. The striving for independence is a similar hallmark of the rehabilitation literature. But as unreal as complete independence is in the field of energy, so too it is in the life of many with a disability. The key seems to be who is defining what is independence. In my personal life space the issue has most clearly surfaced in regard to wheelchair use. Most people with mobility problems have had to face the increased physical difficulty in doing things which once were easy. We had to overcome much reluctance, fear, and even pain to use our muscles while our arms, legs, and even heads rebelled. And once we could reach certain physical goals - take those steps, climb those stairs, scale that hill - we were told explicitly that we must always do them in order to maintain our strength and independence.

In my own case I was always told to push myself to the maximum of my physical capability. Yet I was never given any advice as to what to do when my capability had reached its limits. For me this meant travelling just like everyone else. I would park my car where they parked and walk the full distance to wherever it was that I wanted to go - even in winter on icy sidewalks. No matter that it took me five times as long to get there or that I slipped along the way, or that I arrived at my destination exhausted. The important thing was that I got there under my own steam - physically independent and mainstreamed. But the price I paid was a high one. After awhile fewer and fewer people wished to walk at my pace. Thus either through my embarrassment or theirs, I eventually went earlier or alone or not at all.

In my professional life I repeated this sequence. Arriving at Brandeis with my freshly minted Ph.D., I was greeted by a colleague who gushed about my new office. "It has a beautiful

view," he said, pointing to the third floor window. "Can you make it up there all right?" "Of course," I nearly shouted. No matter that it would take me fifteen extra minutes to reach my destination or that some colleague might have thought me inhospitable when I did not regularly drop in on their offices one or two flights below. Such notions of independence thus meant that until my late thirties I omitted many activities which required considerable walking or where my slowness impeded the progress. Specifically I stopped going on tours, visiting museums, attending large public events, and going with colleagues for a quick lunch or coffee break. I occasionally mentioned this to my varying orthpaedists and prosthetists. They in turn only shook their heads in sad acknowledgement. None of them ever suggested that I use a wheelchair! This only a change in consciousness permitted. And then very reluctantly and only in the last nine years! In fact it is only within the last four years that I have permitted myself the luxury of regularly using wheelchairs in airports.

My point is that in living in accord with someone else's definition of physical independence I, for far too long, contributed to the demise of my own social and psychological independence.

The dilemma becomes even clearer with people who only use wheelchairs, particularly those who are forced to use physical means to propel themselves when electronic means are available. I would argue that there are few physical circumstances of which I am aware where the increased physical independence is worth the decreased social and psychological independence. In the rare situation where the physical exercise is essential, I am sure other forms can be created. And where in the rarer circumstances a substitute cannot be created, why then not have at least two wheelchairs - one electric and one hand-propelled?

As you can see, I'm concerned with whose values define 'independence.' In my more cynical moments, it seems a matter of whom we are dependent on. There seems to be a great fuss about paying for our dependence on personal care attendants, about letting the client control the money, and about the fact that fees may range from $3 to $10. But there seems little argument about our costly dependence on kidney dialysis machines. Could this, I occasionally ask myself, be in any way related to the fact that such dialysis treatments are medically dominated, technologically fascinating and profit-making? Efforts to make us independent of this are greatly resisted. Thus attempts at self and home-dialysis seem to vary more by geographic location than physical condition - ranging from under 15% here in the Northeast to over 50% in the Northwest![6]

The Independent Living Movement crystallizes very well this issue. Its very philosophy proclaims a new notion of independence. Independence, we claim, is not measured by the mundane physical tasks we can do but by the personal and economic decisions we can make. It is not the quality of tasks we can perform without assistance but the quality of life we can live with help.[3] To retain the old physicalist criteria of independence can only ironically contribute to the very isolation and dependence we clearly seek to avoid.

ASSESSMENT - A QUESTION OF PREMATURE CLOSURE

Sometimes operating assumptions are not so visible as in ideas about independence. Sometimes they are buried in more pragmatic matters such as the way rehabilitation programs assess an individual's physical and mental capabilities. That such assessments may be unduly influenced by historical and cultural considerations was illustrated to me by an experience I had when living at Het Dorp.[15]

For those of you unfamiliar with this place, let it suffice to say it is a village in the Netherlands, created specifically to house people with severe physical involvements. People lived there because there were no community alternatives and because no further rehabilitation was possible. While the village did have medical services, there was no formal rehab program. And yet during my stay a few people 'improved' sufficiently to leave the village. While some critics have attributed this to a faulty selection policy, I do not think it was so simple. For many were simply able to experiment with new ways of doing things with no cost to themselves. They were able to fail - and when they did, they could try again. And some did until they eventually 'succeeded.' One implication of this observation is that many programs not only give up too early in the rehabilitation process but also have no systematic way of assessing our long-term progress and capability. In fact most of us with disabilities are never given the chance to learn about new devices.

Here again it is easy to be very concrete. For I am an excellent example - a well-educated, rather informed individual, with good health insurance, interested in prevention, enrolled in a quite prestigious HMO, a staff member of several local hospitals, and a friend and colleague of many eminent physicians. It has been thirty-one years since my polio and twenty-seven since my accident - both incidents which left me with considerable right-side weakness. I thus wear a long leg brace, a back support, limp and use a cane. And yet I have never, in the over twenty-six years since my rehabilitation was "completed," been called in by any of my orthopaedists or prosthetists for a check-up or to discuss new ways I could do things or new devices I could use. I do not mean of course that I have not seen these people but rather that I only did so when something was awry and then quite naturally we all focused on the trouble. Anything now that I do or use today I learned from friends or journals. Now some might argue that that is the American way. I would argue that it is haphazard rehabilitation - a consigning of me and many like me to the "we have done all we could" category. I am not claiming callousness. I am claiming that there exists

a system built on certain assumptions that prevents the rehab world from ever really knowing if they have done all they can.

SAFETY - AT WHAT PRICE?[11]

With such global considerations as a context, I want to examine the effect of similar assumptions on the direct application of rehabilitation technology. An issue of great concern in the design of activities as well as devices for those with disabilities is safety--the protection of the individual from unnecessary harm. While the wish to protect vulnerable people from danger is a worthy goal, it is often achieved at too great a cost. Loring Mandel wrote of this in a play, "Do Not Go Gently Into This Good Night."[10] Melvyn Douglas portrayed a retired cabinetmaker who 'for his own good' was placed in a nursing home. His breaking-point occurred when the staff refused to allow him to use the available woodworking machinery because it was too dangerous. He rebelled. He claimed that he had the right as a human being to run the risk of injuring or losing his finger. Since they disagreed, he quit the home. Most of us are not so fortunate. We do not have the power to quit. The authorities will not let us leave. And we have no place to go.

This is seen most dramatically in regard to people with mental handicaps - those labelled 'retarded.' The tone was set early in this century:

> ...self control and independent life are not for mental defectives, either in their own best interests, or in the best interests of the family, the community, and the nation. Commonsense forbids it. In the nature of things it cannot be. Mental defectives may be nearly or quite self-supporting; they can never be self-controlling or self-directing except in a childish way, and they can never be the masters of their own fate except at the cost of disaster and ruin to themselves and to others - disaster that affects future generations as well as the present generation, and that tends to undermine as far as it goes, the security of the homes and the nation concerned. Mental defectives are permanent children...[9]

It took over sixty years to begin to undo this perspective - to question what in this statement was social fact and what was self-fulfilling prophecy. Through many had speculated about what over-protection might do to such children,[5] it was not until the early 70's that someone gave empirical truth to this fear.

In a study of mildly retarded children, the investigators reported that the more over-protected and controlling the mother was, the more likely was the child to oftentime intellectually have a decrease in I.Q. score and physically to experience poorer muscle coordination.[13] In short, many became 'permanent children' when they need not have.

There is a body of psychological literature which claims that risk-taking is essential to the growth and development of all individuals.[14] Robert Perske summed it up best when he concluded:

> The world in which we live is not always safe, secure and predictable. It does not always say 'please' or 'excuse me.' Everyday there is a possibility of being thrown up against a situation where we may have to risk everything, even our lives. This is the REAL world. We must work to develop every human resource within us in order to prepare for these days. To deny any retarded person his fair share of risk experiences is to further cripple him for health living.[12]

I spent a day recently with a para who races autos and sometime before that with a quad who was learning how to ski. Both of these activities I would not have engaged in BEFORE I got polio! Without trying for a moment to denigrate the achievement and courage involved in their doing this, what else I think they are doing is putting some risk back into their lives where so much has been denied them. Hoping there are no police safety officials reading this paper, I realize my risk defiance comes from a continual neglect of seat belts and an almost congenital inability to keep to the 55 mile an hour speed limit. Given that I travel a lot, I think I am on the way to collecting a speeding ticket in every state.

In short, if society does not let us have normal risk in our lives, many of us will go to extreme lengths to reestablish it. Thus to design an environment or device to prevent any kind of risk may go too far. It may not produce a real life but a mirage of one. There is human dignity in risk. There can be dehumanizing indignity in safety.

DOING TOO MUCH TOO TECHNICALLY

Technology can also do too much for those of us with disabilities. The machines technology creates may achieve such completeness that they rob us of our integrity by making us feel useless. There is an example of this in a very different area but it has relevance here. Many years ago when "the convenience food" business was in its most expansive phase, the manufacturers discovered that where cake mixes were concerned, they had gone too far. Early in their marketing all the ingredients were included. All one needed to do was to add water, stir and then bake - the same formula that worked so successfully with soups. But there was customer resistance and sales faltered. They soon realized that cake making contained some important elements that differed from soup preparation. Baking had more intimate connotations - it had associations with being "fresh" and even "special." As a result, the manufacturers quickly altered their strategy. They not only instructed the customer to add fresh eggs but on the sides of the box they gave hints on how to improve the recipe - how to make it more special, more one's own.

I believe a similar phenomenon is occurring with device use. I have noticed that many disabled persons have invented an addition to their appliance or altered its use to suit their purposes. For years I thought this was merely our way of correcting the faults of our prostheses. But now I think something more is at stake. For fifteen years my own leg brace has not fit properly. No matter what they do, there seems to be one place where within twenty-four hours a pressure sore will be produced. It is, however, a problem which I have solved by creating a special patch which I place over the spot every day. It is clear I have a certain pride in solving something the professionals could not. But I have also done something else. I have made the brace more a part of me because I have given it my own unique stamp. Now again, I am not arguing that the rehab world should stop inventing devices that we need, particularly when we ask for them. But that rather whatever the device, it need not do everything. It may even be worthwhile to encourage us to create things that not only serve us better but make it more our own.

There are other even more subtle ways in which the use of technology has and is going too far - where our very integrity is at stake. There is very little understanding of what happens when bodily parts and functions are replaced by equipment. It is not an unmixed blessing. It has been found in regard to transplants and skin grafts that the physiological body rejects parts which it feels are alien. So too the psychosocial person rejects parts which he or she feels are alien. No one who thinks of himself as independent wants to use even a cane or crutches. And when he does, he often tries to avoid it in public or simply gets angry, as Barry Goldwater did in his 1980 speech before the Republican National Convention. The problems escalate the closer the appliance gets to the human body. Thus it is not at all clear what it means to have as part of one's daily routine the putting on of braces and the strapping on of prosthetic limbs. The adjustment may become more serious - if not psychosis producing - when we become <u>internally</u> attached and thus dependent on machines - from the insertion of pacemakers to the attachment of the kidney dialysis machine. A warning note on this issue was sounded nearly thirty years ago when Francis MacGregor studied the effects of plastic surgery on people with major facial disfigurements. Unprepared for what the new 'me' would look like, there was instead of relief and gratitude profound feelings of distrust, anger, depression and even suicide.[8] I am not, of course, arguing for the elimination of all such mechanical aides but merely that those who use them may neither be as proud nor as grateful as the inventors think they should be. For these appliances alter a sense of self so profoundly as to make the now liveable life not worth living.

There may be a similar problem in the over-technicalization of 'care' such as in the invention of robots or the training of chimpanzees to service, dress and feed quadriplegics. While it might well be cute when one's favorite pet brings in the newspaper or, in rare instances, one's slippers, it is less cute when these involve more intimate tasks. I realize that part of the appeal of machines and animals is because of the intimacy which it may be perceived easier to share. But there may be a long term loss of this short term gain. I did not accidentally use the term 'care' when I introduced this thought. According to Webster's dictionary, 'care' involves:

> painstaking or watchful attention
> regard coming from desire or esteem
> a person that is an object of attention,
> anxiety or solicitude

My point is a simple one - that care, as in the terms 'medical care' or 'personal care', is not merely a technical task. On the contrary, it involves quite personal aspects. To thus objectify this care into a technical service, to replace the human element with a mechanical or animal one, can only lead to the further objectification of the individual receiving that service. Moreover, when the technical side of care becomes so prominent that it becomes the same as care itself, then we have a situation ripe for ethical tragedy. In the fall of 1981 three Boston physicians were convicted of rape. While out on appeal, one of the doctors got a job in another state. He was able to do so on the basis of the recommendations of other physicians, including superiors who later claimed that these other matters (i.e., the rape he had committed) did not affect his practice of good technical medicine![4]

Of course much of the traditional caregiving has also produced problems. Any time that it is patronizing or infantilizing cannot be a good thing. But as bad as such qualities are, they are at least human ones. They reinforce the humanness of the individual involved. To be handled by a machine or animal where once I was handled by a person can only be invalidating of me as a person.

IN CONCLUSION

My conclusions are straight-forward. **We must expand the notion of independence from physical achievements to socio-psychological decision-making. Independent living must include not only the quantity of physical tasks we can do but the quality of life we can lead.** Our notion of human integrity must take account of the notion of taking risks. Rehabilitation personnel must change their model of service from doing something <u>to</u> someone to planning and creating services <u>with</u> someone. In short, unless the rehab world frees itself from some of its culture-bound and time-limited standards and philosophy, we may one day find ourselves in the position of Walt Kelly's Pogo who once exclaimed in despair, "We have met the enemy and he is us."

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FULL PARTICIPATION OF DISABLED PERSONS

Jim Derkson

Disabled Peoples' International, Winnipeg, Manitoba, Canada R3C OB9

ABSTRACT - This paper discusses the societal changes which must take place in order for the disabled persons to be truly integrated. Full participation of disabled persons requires fundamental and far reaching changes in human social organizations, values and understanding. Non-participation is a philosophical, socio-psychological problem rather than an economic or resource problem.

RÉSUMÉ - Cette communication traite des changements qui doivent intervenir dans la société pour permettre aux personnes handicapées de s'intégrer véritablement. La participation entière des personnes handicapées nécessite des modifications fondamentales et profondes dans les organisations, les valeurs et la compréhension de la société humaine. La non-participation est un problème philosophique et socio-psychologique plutôt qu'un problème d'ordre économique ou un problème au niveau des ressources.

Participation is a sharing in common with others and so is inherent in the social nature of man. Broad based participation is essential for the well being of all people and all societies. It is also basic for the promotion of social development.

Full participation of and for disabled people is in many ways a more difficult objective to achieve than prevention or rehabilitation of disabilities because it requires a widespread and basic change of mental structures together with a corresponding evolution of socio-cultural values. It also requires the provision of technology for disabled people and structural changes in social organization and the environment, simultaneously with these changes in mentalities and values. Fortulately, changes in organization and environment and changes in mentalities and values greatly facilitate each other.

Participation is most widely understood as a sharing in common with others. This sharing must ultimately be understood in its broadest sense but is most often referred to here in the sense of sharing activity or experience. Therefore, common human experiences in family life, in the life of the community and in all social, economic and political activities of man constitute full participation. Participation implies an essential equality of experience among the participants; both rights and responsibilities, securities and risks, defeats and victories, alike, are shared in common by full participants. This essential and general equality of experience by those participating together does deny any differences there may be among them. Full participation means a diverse sharing of experience in common with various others in society at large; that is, with all people, not only with those in any particular subgroup.

Archeology and history shows us that some disabled individuals have been participants in all human societies throughout time. Present day societies, too, present us with some disabled individuals who have achieved full participation and often made outstanding contributions to their societies. The participation rates for disabled people however have been far below the rates for the population at large throughout the history of man. This remains the present condition of societies throughout the world in both developing and developed countries. This problem has been recognized in the International Year of Disabled Persons, full participation and equality having been the themes of the year.

Unlike prevention of disability, which is to a larger extent a function of economic and resource factors, non-participation of disabled people is so general and obvious a phenomenon historically of human society in all economic conditions that it must be seen as a most basic socio psychological and even philosophical problem rather than an economic or resource problem. This approach is further affirmed by the fact that most or all human societies invest relatively significant efforts and resources for the overt purpose and with the perceived intention of alleviating the problems of disabled people.

The fact that these investments usually result in further entrenching the disadvantaged non-participating position of disabled people in society also indicates most basic problems in human social organization, values and understandings. These problems mean that very fundamental and far-reaching changes in these areas must be contemplated by those who seek to bring about full participation of disabled people. Those engaged in this endeavour must also expect their most basic understandings of social organizations, values and mental structures to be challenged and perhaps sacrificed to the achievement of increased participation by disabled people.

SOCIO-TECHNOLOGICAL PERSPECTIVES OF (RE)HABILITATION

Ron Levy, Faculté de l'Aménagement, Université de Montréal, Montréal, Québec, Canada, H3C 3J7

Abstract: A structure and definition of the emerging systemic paradigm is developed in order to compare and evaluate the biomedical and biopsychosocial models of health care. The social and technological limitations of both models are identified and speculation is made with respect to future models of health care in terms of technical authority and value authority.

Résumé: Les modèles biomédical et biopsychosocial du domaine de la santé sont comparés entre eux et évalués à partir du paradigme systémique actuellement en émergence. Les limites des deux modèles, sur les plans social et technologique, sont identifiées et une réflexion est amorcée en vue de l'élaboration de nouveaux modèles qui tiennent compte du pouvoir technique et des systèmes de valeurs.

INTRODUCTION

Since the early sixties and the work of Thomas Kuhn (1962), there has been a general acceptance of the view that science, and other human activities, periodically make dramatic shifts in orientation and conviction. Whether or not one agrees with the original Kuhnian notion of scientific revolutions that bring about these periodic changes, or Toulmin's (1972) redifinition of the phenomenon in terms of evolutionary transitions, or Lakatos' (1978) more subtile interpretation of the Kuhnian concept, or Stegmuller's (1979) detailed structuralist approach to this issue, all agree on the fundamental concept that science (and therefore applied science, art and technology) shifts, changes and advances in periodic steps. In addition, there is general agreement that science (and any other human activity) is founded on a specific, clearly defined and structured view of the world, or paradigm, and that this paradigm provides the groundrules for all modes of human action.

These theories of scientific change were established, in part, in order to explain the perceived scientific revolution which began to materialize in the early sixties. It was the beginning of an era which saw the traditional mechanistic paradigm of science move towards, what now can be called, the systemic paradigm of science. Evidence of this shift can be seen in the gradual replacement of the dualistic metaphysical view of the world by a systemic view (an amalgam of monistic, dualistic and pluralistic views). The traditional empirical methodological concepts are being broadened to include analogical and qualitative methods. Causal determinism is being replaced by wider teleological concepts and the traditional epistemological reductionism is being replaced by a more structural/phenomenological form of analysis (Battista, 1977). All fields of natural and physical science, applied science and consequently technology, production and the arts began to shift in the sixties, and are shifting still today, towards a general systemic paradigm (Levy, et al, 1983) (see figure #1). The consequence of this general paradigmatic transition and its impact on the health field and (re)habilitation is the subject of the rest of this paper.

Figure # 1

CHARACTERISTIC	MECHANISTIC PARADIGM	SYSTEMIC PARADIGM
Metaphysic	Dualism	Systemism
Methodology	Quantitative - *Deductive*	Quantitative/Qualitative - *Inductive, deductive, descriptive, historical, psychological.*
Epistemology	Reductionism - *Atomism*	Structural/Phenomenological - *Atomism, holism, systemism*
Teleology	Single-determinism - *Causality*	Multiple-Determinism - *Chaos, randomness, causality synergism, conflict, purposefulness.*
Ontology	Atomic/Molecular - *Physical, chemical, biological*	Ecological - *Physical, chemical, biological, social, psychological, technical.*

TOWARDS A SYSTEMIC DEFINITION OF A PARADIGM

At the outset, it is important to emphasize that paradigms are the all embracing contexts to human action and they provide the structure through which we perceive the world. Wartofsky (1979), aids us in conceptualizing more precisely the notion of a paradigm when he describes it in terms of an approach which helps to legitimize questions one may ask about the world and which helps identify what entities exist in the world. The paradigm, thus, serves as a heuristic for the formulation of problems and the methods used in their solution. In other words, a paradigm is a belief system which a group of people share and which is composed of, at least, four interdependent paradigmatic fields (Levy, et al, 1983). These four fields are:

1. The Epistemological Field, which is shaped by the activity of 'abstracting' and directed by modes of cognition, value systems and knowledge. Knowledge is viewed both in terms of explicit knowledge which manifests itself in the form of external verification and implicit knowledge which manifests itself in the form of internal experience. Value systems are viewed as a complex of issues involving beliefs, attitudes and convictions and which include, for example, values of life, health, and freedom from pain and suffering (Willard, 1982). In short, the epistemological field is concerned with cognitive significance, human values and knowledge ranging from general philosophical theories to specific action related knowledge.

2. The Ontological Field, which is shaped by the activity of "being" (Bunge, 1981) and described in terms of physical, chemical, biological, psychical, social and technical modes. These modalities of "being" prescribe all organisms (whether natural or transformed), things, entities or systems. The ontological field defines the substantiality of existence and constitutes the percieved substantiality of the world.

3. The Methodological Field, which is shaped by the activity of 'operationalizing' and described in terms of quantitative, qualitative, objective and subjective modes. These are the operational imperatives of human action and is directly linked to theoretical knowledge, the functionality of known things, and the purposefulness of human intervention. The methodological field is also structured in terms of deductive, inductive, descriptive, historical and psychological procedures and modelled as a function of the approaches of serendipity, investigation, evaluation, planning and design.

4. The Teleological Field, which is shaped by the activity of "becoming" and defined in terms of the modes of chaos, randomness, causality, synergy conflict and purposefulness (Bunge, 1981). The teleological field provides the intentionality or determinism, whether purposeful or not, necessary for any explicit or implicit human action (such as, for example, scientific inquiry).

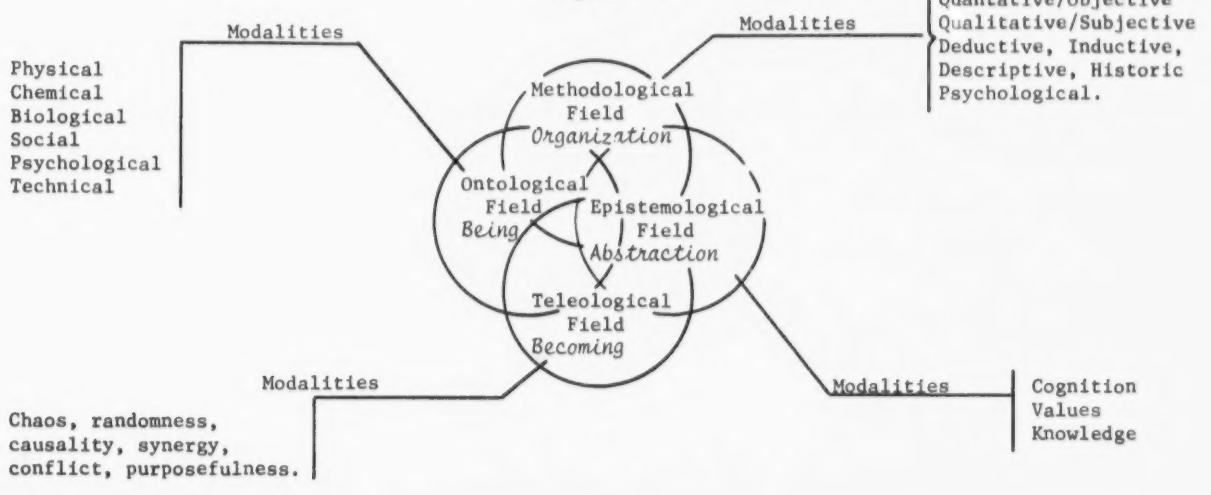
It is emphasized that none of the four fields should be viewed separately. Each field contains the others in a synergistic manner, forming an integrated, interconnected system. For example, any study into what the human individual is (i.e. being) must be coupled with, (a) the intentional mechanisms of human conception, adaptation and extinction (i.e. forms of becoming), (b) the abstractions of human cognition, values and knowledge, and (c) the operationality of human organization (see figure #2).

The above definition and structure of what constitutes a paradigm may now be used to explain the differences between, say, models of (re)habilitation based on a mechanistic paradigm and those based on the emerging systemic approach.

(Re)habilitation Models

The interdisciplinary field of (re)habilitation has been dominated by the biomedical model of medicine since the early 30's. The biomedical model itself is predicated on the scientific and industrial imperatives of the past one hundred years or

Figure # 2



so, and the traditional mechanistic paradigm. Since the mechanistic paradigm is currently in a process of transition towards systemism, it is therefore normal that the biomedical model is being rethought, reworked and changed at the same time. In recent years, a plethora of new schools of thought have arisen and diverse models of medicine and of (re)habilitation have been produced (for example, Halstead and Halstead, 1978; Anderson, 1975; Anderson, 1978; Kielhofner, 1978; De Jong, 1979; Phillips, 1980; Kielhofner and Burke, 1980). The overall trend of these models is towards systemism and they have been amalgamated into what is now called, and accepted as, the biopsychosocial approach to health care. It is perhaps pertinent to ask, at this point in time, whether or not the biopsychosocial model is in fact reflective of the emerging systemic paradigm?

One way to answer this question is to use the overall definition of a paradigm given above, and to compare the biomedical model and the biopsychosocial model in terms of the four paradigmatic fields. In this way the scope of each model may be defined and their limitations with respect to the systemic paradigm identified. Figure #3 briefly outlines the major characteristics of each model.

The primary and most fundamental characteristic of the biomedical model is that it is predicated on the reductionism of the mind-body duality. In addition, for the biomedical model to have meaning within the mechanistic paradigm, all elements of the model have to be reduced to atomic or, at best, molecular terms. All elements in the biomedical model are in fact reduced to either physical, chemical or biological terms to be coherent with the mechanistic perspective. Any modalities outside of this limited ontology are strictly not treatable by the model (Engel, 1981). Thus, the biomedical model does not, and cannot, make provision for the person as a whole nor for the existence of modalities of a psychological, social, technological or ecological nature. As such the biomedical model can only maintain its validity within the confines of laboratory intervention.

The biopsychosocial model is predicated on a pluralistic metaphysic as apposed to the dualism of the biomedical model. In addition, the biopsychosocial model, because of its systemic context, incorporates a larger ontological spectrum. All elements within the biopsychosocial model are reduced to physical, chemical, biological, social or psychological terms. Thus, two ontological modalities have been added to the set found in the biomedical model. Strictly speaking, whilst the biopsychosocial model does make provision for the person as a whole (a vast improvement over the biomedical model) it does not make, and cannot make, provision for the person and his environment as a whole. Nor for that matter does the model make provision for the existence of ontological modalities of a technological or ecological nature.

It is this analysis that brings one to realize that the biopsychosocial model, so often seen today as a revolutionary departure for the health field, continues to have considerable limitations and is not fully predicated on the scope of the emerging systemic paradigm. The biopsychosocial model is therefore more of a transitional model between the biomedical model based on mechanism, and some new and future model, as yet undefined, based on systemism. It is therefore of some interest to begin to speculate as to what characteristics and modalities need to be added to the biopsychosocial model of health, so that it conforms and reflects more accurately the complex richness of the systemic paradigm.

Technology and Value

Since the overall scope of this conference concerns rehabilitation engineering, let us confine our speculations to this sector. As mentioned above, neither the biomedical model nor the biopsychosocial model incorporate the modality of technology at the same level as the physical, chemical, biological, social or psychological modalities.

It is important to note that the use, here, of the term "technology" does not refer only to hardware such as instruments, tools, devices, aids, etc. The central meaning, and the more fundamental

Figure # 3

CHARACTERISTIC	BIOMEDICAL MODEL *Mechanistic Paradigm*	BIOPSYCHOSOCIAL MODEL *Quasi-Systemic Paradigm*
Metaphysic	Dualism - *Mind-body*	Pluralism
Methodology	Quantitative	Quantitative/Qualitative
Epistemology	Reductionism	Phenomenological
Teleology	Single Determinism - *Causality*	Multiple Determinism - *Causality, conflict, synergy*
Ontology	Atomic/Molecular - *Physical, chemical, biological*	Social/Psychological - *Physical, chemical, biological, social, psychological*

meaning, is taken to be that of "techne", i.e. the set of principles involved in the production of an artefact. "Techne" implies a knowledge of principles and as such resembles very closely the concept of "episteme" or the interrelationships among cognition, values and knowledge. Technology, therefore, should not be associated solely with the means of making concrete objects but must also include the knowledge of, and the ways of doing work, i.e. technological praxis. Technology in its broadest sense personifies the principles of work, the way we organize work and labour and how we provide the means of production of specific artefacts, for example, the principles, organization and means of production of health care (Reiser, 1978; Harding, 1978). It is within this definition of technology or "techne" that the linkage to social concerns is made and the notion of human values and ethics related to techne becomes paramount. Thus, it is imperative that, for example, we interlink such concepts as technique and knowledge, technology and purpose, and object and value. This kind of interfacing was all but impossible to treat within the mechanistic paradigm but which is omni-present in the systemic approach.

Looking now at the role of technology in the traditional biomedical model, we find its expression is indeed very limited and reduced to the single notion of technique. It is interesting to also observe that the evolution of the biomedical model and the practice of the medical and paramedical professions during this century has been dominated in general by the reign of science and in particular by technique. This reign has culminated in professional specialization and the centralization of health care services (Harding, 1978). Indeed, the transformation of health care by "science and technology" was carried out in the name of precision, objectivity, standardization and efficiency (McWhinney, 1978). However, what is usually missed in the analysis is the fact that science and technology also influenced health care production. Modern day production of health care follows very closely the technique dominated, material production model found in industry where the central aim is to achieve centralized control of services and division of labour. This approach is also the basis for the extraction of a maximum of profit for a minority group of professionals. It must be emphasized that the biomedical model or the industrial model of medicine, is not simply the product of the reign of science and technology, but more a product of a paradigm, the mechanistic paradigm, which treated technology only as a means to achieve ends and not as an epistemic component of the whole. It remains merely to reiterate that technology is not simply manifested in physical artefacts, nor only in organizational procedures, but also in value systems and knowledge. This latter issue is related to the way we perceive the utility of science, technology, art, production and labour and how we intergrate these perceptions into a model of health care.

Today, with the changing of metaphysical perspectives, as we move from a mechanistic to a systemic paradigm, the objectivity of mechanistic science is being questioned and the values of technology are being reinterpreted. The myth that health care is best carried out through a centralized system of control based on medical institutions is being criticized and the traditional practices which serve to preserve social privilege are being renounced (Harding, 1978).

TECHNICAL AUTHORITY AND VALUE AUTHORITY

Consider, as away of concluding, the current notion that individual health needs are factual observable data about people. This notion is in itself, when viewed within the biomedical perspective, not at all contentious. Needs viewed as facts about people can be seen to be directly related to, and identified by, medical science. Human needs have been generally percieved as facts and consequently their identification is seen to be carried out in an objective, detached way. Needs as facts are believed to be directly linked to the scientific process itself. But are human needs indeed facts (properties, states, processes, relations) about people?

Needs as expressed as facts have become so widespread within the biomedical model that it can be said that health providers have become more concerned with the reductivistic process of identifying observable health facts about citizens than with their actual health goals. This approach has taken on even a moral flavour. Willard (1982), expresses this morality and its associated circular thinking in the following:

> "If medical science and technology can do it, then people need it. If people need it, people ought to have it. If people ought to have it, medical science and technology ought to do it. Ergo, if medical science and technology can do it, then they ought to do it (Willard, 1982, p. 269).

He goes on to argue that needs are not facts about people, but rather personal goals, things people value. Needs seen as values and not facts change the very basis of technological intervention. It is a distinction between an authority based on the judgement of measurable facts and an authority based on the judgement of non-measurable values (Veatch, 1982). It is this very critical issue, where value authority is juxtaposed with that of technical authority that puts us at the crossroads between mechanistic reductionism and structural systemism. We have to stop believing that by developing increasingly sophisticated techniques we can improve our information about health needs as facts. That is clearly a reductivistic and mechanistic approach to health care. We need to qualify that approach and begin to think in terms of increasing our sophistication of knowledge of health in order to improve our perception about health needs as values.

The systemic paradigm is one which emphasizes this kind of value-oriented approach and the interconnectivity of all modalities of human activity. It therefore goes beyond the mechanistic orientation based strictly on technical authority and its limited epistemological, methodological, ontological and teleological modalities. The

systemic paradigm promotes the authority of value and,as such,brings with it a view of the world which is dynamic and complex and therefore more difficult to handle and manipulate. It is the price we have to pay if we wish to wrest ourselves from the inequalities, injustices, limitations and simplifications of the mechanistic paradigm. It is the price we have to pay to advance with the current paradigmatic revolution. It is the price we have to pay to move away from the hegemony of the biomedical model(based uniquely on technical authority),towards a model of health care based on the authority of techne and values.

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SPECIAL SESSION/SÉANCE SPÉCIALE 6

COMMUNICATION AIDS FOR THE HEARING IMPAIRED/

AIDES À LA COMMUNICATION DESTINÉES AUX MALENTENDANTS

Chairperson/Président:

H. Levitt
City University of New York
New York, U.S.A.

SENSORY AIDS FOR THE HEARING IMPAIRED: CURRENT ISSUES AND LONGSTANDING CONTROVERSIES

Harry Levitt
Center for Research in Speech and Hearing Sciences, City University of New York, Graduate Center, 33 W. 42 Street, New York, N.Y. 10036

ABSTRACT - Sensory aids for the hearing impaired are categorized in different ways. A three-way classification system is suggested. The issues and controversies surrounding the various types of sensory aids are discussed.

RÉSUMÉ - On catégorise de différentes façons les appareils d'assistance sensorielle pour les malentendants. On propose un système de classification à trois éléments. On discute des questions et controverses entourant les divers types d'aides sensoriels.

Sensory aids for the hearing impaired can be sub-divided in many different ways. Possible methods of classification are i) by function, e.g. is the aid intended to supplement or replace the impaired auditory system? Is the aid intended for speech reception, speech training, or both?

ii) by mode of stimulation, e.g., auditory, tactile, visual, or electro-auditory

iii) by display type, e.g., time waveform, spectrum display, or speech-feature display.

There are other methods of classification but the above three factors provide a concise three-way method of classification that covers all of the sensory aids that have been developed and also brings to the fore common underlying issues that affect many different types of sensory aids. The common hearing aid, for example, is an auditory aid designed to supplement the impaired auditory system and serves as both a speech-reception and speech-training aid.

Issues that confront the field involve each of the above factors. A controversy of long standing involves that of oralism v.s. manualism. This controversy extends well beyond the issues surrounding sensory aids, per se. The oralists believe that maximum use should be made of residual hearing and that through acoustic amplification and effective speech and auditory training, including lipreading, hearing impaired individuals can acquire the skills they need to function effectively in a hearing world. They emphasize speech and auditory training during a child's early years, because the hearing-impaired child will be at a substantially greater disadvantage in acquiring oral language later. They point to the fact that the communication skills of children who become hearing impaired after they have acquired speech and language are generally superior to those of the prelingually impaired.

The manualists believe that sign language is the natural language of the deaf and spoken language is of little importance. Consequently, they feel that attempting to teach speech and auditory communication skills to a profoundly hearing-impaired child is bound to end in failure, which in trun will lower the child's self-esteem and could result in psychological damage. While some profoundly hearing-impaired children will never acquire a modicum of proficiency in spoken language, the oralists counter, some can and have acquired oral communication skills and are able to function effectively in a hearing world.

Basically, the philosophical battle lines between the two groups are drawn over the issue of integrating the hearing impaired into the larger, hearing world. Most oralists believe that integration is both necessary and desirable ; many manualists feel that it is neither.

The educational philosophy of total communication adopts the compromise position that profoundly hearing-impaired children should be taught both to speak and to use sign language. Though most of the schools for the deaf in North America have ostensibly embraced this point of view, there are vast differences among them in the importance they assign to speech training. Despite their educational label, many of the total-communication schools follow the manualist philosophy de facto. Another compromise position is cued speech, which advocates that the speaker use hand gestures to reduce ambiguity in sounds that are visually identical when lipread (Cornett, 1977)

Each group advocates the development of sensory aids that will harmonize with its own philosophy. The manualists, a small but very influential segment of the hearing-impaired population, consists mostly of profoundly hearing-impaired individuals many of whom grew up with sign language as their first language. They are primarily interested in sensory aids that facilitate communication by means of the printed word and aids that facilitate the learning of sign language. Interestingly, they have not yet shown great interest in devices that would permit communication by sign language over the telephone using low-bandwidth video channels.

The oralist philosophy is embraced by most of the moderately hearing impaired and severely hearing impaired and a small population of the profoundly hearing impaired. The oralists are interested in all types of sensory aids except those

involving sign language, but they are particularly concerned with auditory aids, such as conventional hearing aids, aids that supplement lipreading, and aids for speech training.

The total-communication group consists primarily of severely or profoundly hearing-impaired people. Since many schools for the deaf have recently switched to the total-communication philosophy, the proportion of hearing-impaired adults who subscribe to it is steadily growing. Their interest in sensory aids is eclectic; any device that will help them communicate more effectively, either orally or manually, is well received.

The cued-speech group is very small, because both speaker and listener need to learn special hand cues. If a practical, automatic cueing device is developed, the size and importance of this group is likely to increase dramatically.

For persons with a fair degree of residual hearing, acoustic amplification is generally regarded as the most effective approach. Another possibility, within the framework of acoustic amplification, is to recode the speech signal so as to convey speech information in an alternative form. In the case of severe or profound sensorineural hearing impairment, it is quite common to find some hearing in the low frequencies (up to about 1000 or 2000 Hz) and very little, if any, hearing above 2000 Hz. A form of acoustic recoding known as frequency transposition shifts the inaudible speech energy in the high frequencies into the low-frequency region, where it produces distinctly audible cues.

Transposition works well with voiceless fricative sounds. Since these sounds have very little low-frequency energy, the superposition of coded signals representing the high-frequency structure of the sound destroys very little low-frequency information. The success of transposition in recoding sounds that contain information in both the low and high frequencies has not been proved.

Experimental evaluations of several different transposition systems show improvements in speech sound reception under restricted conditions, such as in single-word speech identification tasks or in the use of speech-training aids designed to improve production of the fricative sounds (Levitt, Pickett and Houde, 1980). Evaluations under more general conditions have yielded conflicting results. Some studies show small improvements; others show no measurable improvements in comparison with conventional acoustic amplification. A major difficulty in using and evaluating frequency transposers that radically alter the speech signal is that the users must learn a new code. It could be argued that the negative experimental results are due primarily to the subjects' not having yet learned the transposed speech code.

It has also been argued that if a radically different speech code is to be acquired it is best done during childhood, when children are beginning to learn the sounds of speech. This hypothesis is very difficult to test, and there are ethical questions involved in doing so. Conceivably, a hearing-impaired child could acquire speech and language much more readily if all the important speech cues were transposed to his or her region of residual hearing. If such an experiment failed, however, the child's acquisition of speech and language could be retarded further that it would have been otherwise. The difficulty of reliably measuring the amount of residual hearing in a hearing impaired infant makes this kind of experiment even riskier. Children with a fair degree of residual hearing can acquire reasonably good speech and language skills with conventional acoustic amplification. Radical distortions of the speech signal could cause irreparable damage to the normal processes of development in such children.

Many researchers argue that the auditory system has inherent speech-feature detectors that severely restrict the ability to learn any radically different speech codes. They argue further that the information capacity of a severely impaired auditory system is extremely limited and that to be intelligible, the information content of recoded speech signals necessarily exceeds this capacity.

Supplementing or bypassing the impaired sensory system by means of another modality is a very attractive option in the development of sensory aids for the hearing impaired. Initial attempts at such an approach simply displayed the speech waveform tactilely or visually (Levitt, Pickett and Houde, 1980). A person could separate weak from strong sounds and determine whether speech was present, but not much else. More sophisticated methods, which provide either spectrum or speech-feature displays of the speech signal, have since been developed. Although some very useful results have been obtained with these displays, the goal of effective speech communication through another modality remains elusive.

Several distinct schools of thought have emerged regarding the most effective type of display. One group (Liberman et al., 1968) argues that speech is a special code and the auditory system a unique decoder. It is unrealistic, according to this view, to expect either the visual or tactile system to substitute effectively for an impaired auditory system. This argument is used to account for the relatively modest gains obtained with nonauditory techniques. Proponents of this view feel that visual or tactile displays have served as useful supplements to lipreading or as speech-training aids, but not as substitutes for the auditory system.

A counterargument to this view (Houde, 1980) contends that the gains realized in communicating speech through alternative modalities have been modest because of such factors as the poor resolution of early experimental devices, the use of inappropriate training strategies, and exposure to displays for limited amounts of time. In this view, a person can understand speech through a display if information is properly presented and the person is thoroughly trained. It has been demonstrated that a person can read and understand a spectrographic display of speech (Cole, et al., 1979). Though the process is very time-consuming and impractical as a means of cummunication for the deaf, the methods used in reading sound spectrograms could prove extremely useful in designing more effective displays.

There may be critical periods in a child's development when the ability to learn speech is at a peak. If effective displays were provided to a child during these early stages of speech and language development, such displays would be far more effective as communication aids later.

A third school of thought believes that regardless of whether speech is special, it is possible to communicate effectively using visual or tactile symbols that reflect the features of speech in a well-organized way. One can understand speech, for example, through the printed word or through lipreading, even though there is little or no auditory input. In the somewhat cumbersome Tadoma method of communication, deaf-blind people pick up speech cues by touching speakers' faces and feeling their articulatory movements (Norton, et al., 1977).

The success of these methods raises questions about whether more effective displays could be designed for transmitting only the important features of speech. Several experimental aids have been developed that provide supplemental cues to reduce the ambiguity that occurs in lipreading. Positive results have been obtained with many of these devices, usually in the form of increased speech reception skills, but the size of the improvements are relatively small compared to the overall goal of making speech fully intelligible.

Automatically extracting important features of speech is a major technical difficulty in creating effective displays. This problem is essentially the same as that underlying automatic speech recognition. If a reliable automatic speech recognition device operating on unconstrained continuous speech could be developed, it would then be a simple matter to convert such a device to a reliable speech-feature indicator, or vice versa.

Several papers at this conference are concerned with applying the technology of automatic speech recognition to the problem of developing a practical visual speech recognition system for the deaf. A balance may need to be reached between visual speech displays that are easy to generate automatically but are very difficult to read by humans (the spectrogram, for example) and displays that are easy to read but are very difficult to generate automatically (such as the printed output of an automatic speech recognition device) (Levitt, et al., 1983).

The hearing impaired are increasingly using aids that take advantage of the printed word, such as captioned television or teletypewriters. Such methods can be extremely effective ways to communicate, but they are not without serious shortcomings. An automatic speech recognition device would go a long way toward solving one major problem with captioned television-the time and cost involved in producing the captions.

Telephone aids for the hearing impaired could benefit enormously from the insightful application of modern signal processing technology. In many cases, inexpensive, minor modifications to existing computer systems would suffice. Many inexpensive pocket computers have an audio output used for recording programs and data on audio casettes. With a slight change in frequency, these audio signals could be used by the hearing impaired to communicate over the telephone (Levitt, 1982).

Inexpensive personal computers have several advantages as communication devices: They cost much less than conventional teletypewriters and they have both memory and logic. Word processors designed specifically for the hearing impaired, for example, could store frequently used words and phrases in an easily accessible format and then print them out at the touch of a button, thus reducing considerably the time spent typing out messages in current telecommunications devices. Because hearing-impaired people might perceive computers as difficult to use, it is important that computers programmed to operate as telecommunications devices be at least as easy to use as conventional teletypewriters.

Direct electrical stimulation of the auditory system is a relatively new development. This surgical technique bypasses the nonfunctioning sensory cells and provides a useful input to the auditory system at the neural level. It benefits the profoundly sensorially impaired, but not the neurally impaired.

Extracochlear electrical stimulation, in which a point peripheral to the cochlea is stimulated, is by far the safest direct stimulation approach. The operation is reversible, as the stimulator can be removed without damaging the auditory system. The major limitation of extracochlear stimulation is that only one channel of limited bandwidth is available. It does provide the psychological benefit of allowing people to hear again, albeit very little, and it has proved valuable in supplying voice-pitch information to profoundly deaf individuals. The cues about pitch and intonation are a useful supplement to lipreading and provide important feedback for monitering one's own voice (Douek, et al., 1977). Methods of processing speech signals so as to make most effective use of extracochlear stimulation are currently being investigated.

Inserting electrodes into the cochlea is another method of direct electrical stimulation. Each region of the cochlea is sensitive to different frequency components in the speech signal, and in order to transmit intelligible speech, several frequency regions must be stimulated independently. Independent electrodes can be used in a cochlear implant, thus providing the possibility of multichannel stimulation. Since the electrical fields generated by intracochlear stimulation are fairly diffuse, a sophisticated combination of skilled surgery and precise engineering is required to achieve a true multichannel cochlear implant (Levitt, Pickett and Houde, Part VIII, 1980).

Research currently is focused on how to process the speech signal for multichannel implants so as to maximize intelligibility. Despite the much heralded publicity abouth cochlear implants, researchers are still asking the same fundamental question: Can the speech signal be recoded so that it is intelligible to an impaired auditory system of limited channel capacity? This question is not very different from that posed with respect to visual and tactile displays of speech.

Researchers have also experimented with the single-channel cochlear implant, but it has proved to be among the least promising implants largely

because it combines all the dangers of cochlear implantation with all the disadvantages of single-channel stimulation. There is no evidence, for example, that single-channel cochlear implants provide benefits superior to those obtained with the much safer extracochlear stimulation. In addition, any cochlear implant does irreversible damage to the very delicate structures within the cochlea, including the destruction of any remaining intact sensory cells. In some cases, evidence shows that a cochlear implant may interfere with the sense of balance (Bilger, et al., 1977). Despite its obvious disadvantages and the availability of a much safer alternative, the single-channel cochlear implant procedure is being performed at an increasing rate.

A third form of electrical stimulation involves implanting electrodes in the auditory nerve (Simmons, 1966). Results similar to those obtained with cochlear implants have been reported. A disadvantage of the nerve implant is that the electrode array cannot be located precisely enough to allow consistent tonotopic stimulation (that is, each electrode stimulating a specific frequency region). Because of the well-organized layout of auditory nerve fibers in different frequency regions of the cochlea, however, consistent tonotopic stimulation can be obtained with a multielectrode cochlear implant.

A further approach is to stimulate the auditory cortex itself by means of electrodes placed on the surface of the auditory area of the brain (Dobelle, et al., 1973). This approach involves extremely complex problems of electrode placement and signal processing and is too difficult and dangerous to warrant consideration as an imminent aid to communication.

Most hearing-impaired children have a doubly severe handicap: They have difficulty understanding speech, and they also have difficulty producing intelligible speech. This is because they lacked auditory input during the critical early years when speech is acquired and because they are unable to monitor their own speech production effectively.

Speech-training aids have been relatively successful in improving the speech of the hearing impaired. These devices provide visual and/or tactile displays of the speech features that supplement auditory cues available through acoustic amplification. Researchers are currently attempting to determine which speech features should be displayed and how they should be displayed. The displays that have been most successful show the fundamental frequency contour, the degree of nasalization, and the spectral characteristics of fricative sounds (Nickerson and Stevens, 1973). Positive results obtained with this system have led to the development of a relatively inexpensive speech-training aid using personal computers.

More effective speech-training aids await the development of reliable procedures for automatic extraction of speech features. Because only one speech feature at a time need be extracted and displayed, the task is not as difficult as that involved in developing automatic speech recognition devices. In addition, for speech training, miniature sensors can be placed on the speaker to obtain articulatory information that would be extremely difficult to extract automatically from the acoustic speech signal.

The size of speech-training aids also limits their effectiveness. Most of the devices are desk-mounted, requiring the child to come to the device, which severely limits access to the aid. Wearable devices, which would provide continuous feedback on specific features from the child's own speech production (as well as good examples from the teacher) would do much to facilitate the speech-learning process.

The pedagogical problem of integrating speech-analyzing aids into the speech-training curriculum is another issue deserving of careful consideration.

The papers that follow address most of the above issues in greater detail. This paper is based on material prepared for a recent review by the author, Signal Processing for the Communicatively Handicapped, in Trends and Perspectives in Signal Processing, 2, 15-26, 1982. Preparation of this paper was supported by PHS Grant # NS 17764.

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REVIEW OF HEARING AID RESEARCH

M. Picard, Université de Montréal, Montréal, Canada H3C 3J7

ABSTRACT. The last ten year of hearing aid research are reviewed. Three points are emphasized: 1- efforts to define desirable attributes of amplifying devices; 2- by-products of acoustic research; 3- innovative technology as they are foreseen today.

RÉSUMÉ. Le présent article passe en revue la recherche en amplification auditive des dix dernières années. Trois aspects font l'objet d'une attention particulière: les vertus que doit posséder l'aide auditive, les retombées de la recherche acoustique et les technologies nouvelles.

The beginning of the decade will probably be remembered in history of hearing aid research for moving into an unprecedented introspective stage. While reviewing 50 years of past research, Studebaker (1) concluded "progress has been painfully slow (...): after half a century effort, the research litterature does not contain a concensus or even substantial objective support for a type of hearing aid selection procedure". Comments of similar nature were voiced about the research effort on linear amplification, amplitude compression and frequency lowering: "Generally speaking, concluded Braida et al. (2), the research reviewed (...) was far form inspiring". Even hearing aid engineers have complained against the so-called "technology gap"(3); that is, the lack of correspondence between the body of knowledges specifying the hearing-impaired need and technical solutions available. As Killion (4) put it, "we have reached the point where there are virtually no engineering limitations to hearing aid performance. Limitations (...) in future will be caused by a lack of solid evidence as to what to engineer".

That is not to imply hearing aid research has come to a standstill: in spite of criticism as to the effect hearing aids of 1982 bear resemblance to the one of 1972 or, in some instances, to the one of 1962 (3), auditory prosthesis have never been as flexible nor did they perform with such acoustic fidelity as they are able of today (3-5). In fact, hearing aid research seems to enter a new era: it is redirecting after a decade of isolated efforts and lack of communication between psychoacousticians and engineers.

In spite of impeded research progress, accomplishments during the last ten years have been numerous and significant. They can be classified into three broad categories: there have been efforts to identify the needs of impaired ears and accordingly, desirable attributes of amplifying devices. This work was carried out mostly by psychoacousticians and/or audiologists. Engineers have also applied many known solutions and technologies to the design of hearing aids. Finally, there has been concern of scientists to develop new technologies tailored to meet the needs of impaired listeners.

1- Needs of impaired ears and desirable attributes of hearing aids

Impaired hearing was studied extensively over the last decade. Accordingly, a large amount of informations has been cumulated. In a multivariate analysis of impaired auditory functions, Festen and Plomp (6) identified alteration of frequency selectivity and temporal integration as determinants of auditory disturbances manifested in sensorineural hearing loss. Consequences of such alterations are still being reviewed and documented (7-9). Degradation of frequency selectivity is reported to deteriorate the processing of speech in the following five ways (9): 1- it breaks down the ability to separate out individual formant frequencies as a consequence of increased effective bandwidth; 2- it induces pathological upward spread of masking, leading to increased masking of low level high frequency formants by higher level lower frequency formants; 3- it deteriorates the detection of signals in the presence of background noise, as a result of an increase in critical ratio; 4- it alters the ability to avoid "party cocktail" type interference because of the possible dependence of masking level differences on normal critical band; 5- It can even degrade the ability to extract pitch information. As far as deterioration of temporal integration is concerned, it can hamper the perception of rapid transient speech cues (10) because of masking (central and backward) or perceptual persistence. It can also have a synergistic effect on the ability of impaired listeners to analyse speech transmitted in

reverberant enclosures because of interacting echo and perceptual persistence (7).

Better understanding of impaired hearing has lead psychoacousticians and audiologists to specify essentially three desirable attributes of hearing aids for improved benefit. Problems of frequency selectivity pin-pointed the acute need for inclusion of sophisticated amplitude processing capabilities (11, 12, 2), including multi-channel compression plus frequency equalization (13, 14). Defective frequency selectivity and temporal resolution also called for devices that prevents contamination of amplified speech by noise and reververation (15-19). Finally, works on hearing aid selection procedures have stressed the need for selective amplification (20-23) securing for amplification of speech energy up to 6 KHz (22).

2- Improvement of hearing aids through existing technology

Engineers have addressed the question of research priorities in amplification far differently than psychoacousticians and audiologists. Current technology has been applied to hearing aids from three different fields; that is, the one of acoustical measurement and development of miniaturized transducers, the one of microelectronic and the one of telecommunication engineering.

A- Electroacoustic measurement of hearing aid and transducers technology

The introduction of an "ear-like" coupler in the early seventies apparently stimulated activity in hearing aid acoustic research (24). New and significant publications on earmold acoustics and "plumbing" (25-28), in connection with mannikin measurements and investigation of the performance of miniaturized transducers opened the way to smoothened wideband frequency response curves in hearing aids (29, 4, 30). Also evolving from this research effort, were significant progress in the direction of a more efficient control of acoustic feedback (31, 32). In addition, booming research in this field has lead to an in-depth understanding of hearing aid behaviour, both normal (33, 34) and abnormal (35). This included an appraisal of the limited benefit of directional microphones in noise and reverberation (36). Finally, progress in miniaturization is clearly exemplified by the recent introduction of canal hearing aids (3).

B- Innovative microelectronic and hearing aids

The advent of integrated circuits and computer science has led hearing aid technology into a new era of sophistication. Some innovative solutions have recently been reviewed by Cole (3). They include the production of very flexible instruments; that is, devices having as many as six ajustable controls. Many amplitude-processing circuits can also be manufactured nowadays: short-term AGC circuitry including systems governed by the manual volume control as well as two-channel compressors. Devices that electronically suppress acoustic feedback through notch filtering and phase shifting techniques are also available. Finally, many innovative designs like automatic high-pass filtering, multiband and look-ahead compression, programmable hearing aids can be realized with existing technology.

C- Hearing aids with FM reception capability

Back in the sixties, hearing aid engineers added FM reception capability to auditory prosthesis (37) in order to alleviate the deleterious effects of noise and reverberation when the hearing-impaired is far from someone he is listening to. This move came as an isolated contribution to the body of hearing aid research. As such, the application did not benefit from miniaturization. Because of the conservative attitude of both the legislator (38) and acousticians (39), it was also limited to the classroom situation. This is unfortunate, however, since the strategy was shown to be most effective for reducing the adverse effects of noise and reverberation (40,41).

3- Exploring new avenues for hearing aid development

In spite of recent technological advances and sophistication attempts, current hearing aids are of limited use to cope with speech processing deficiencies experienced by the hearing impaired. In particular, they fall short of having the capability to separate out speech from noise and reverberation but for FM systems. Also, current devices are limited to a palliative role. In no way, they can pretend to the status of prosthesis; that is, a replacement solution for a non-functional auditory apparatus. Accordingly, they are hopeless for those individuals having no tracable hearing, but for gross auditory and/or vibro-tactile sensations. New technologies are under way to meet these critical needs.

A- Hearing aids with signal processing capabilities

Strategies to separate out speech imbedded in noise and "dereverberation" process as it relates to hearing aids have been given close attention in the late seventies. Searchers like Graupe (42), Berkley (43), Lim (44) and Schafer (45) proposed both analog and/or digital avenues. Yet, no solution has been taken out from the laboratory because of the requirement for processing techniques which are both efficient and compatible with the many constraints of hearing aids namely, miniaturization, reduced supply voltage and current. With the advent of

VLSI circuits, however, prospects seem very good for achieving sophisticated signal processors in the very near future (45).

B- Cochlear implants

In the early seventies, direct electrical stimulation of the auditory nerve through cochlear implants was proposed as a prosthesis for profoundly deaf adults. U.S. programs developed rapidly, relying almost without exception on a single-electrode stimulator (46, 47). At the present time, one program is even extending its activities to children (46). Perception with current devices, however, remains crude: at best, single-electrode implant allows for partial restauration of tonal sensation, detection of speech and differentiation of some stress patterns and/or familiar environmental sounds (46,47). Therefore, speech discrimination does not seem attainable with single-channel technology as it exists nowadays.

In France, multi-electrode devices were used right from the beginning; that is, back in 1973. Results are more promising: even if they are scarce, some patients apparently reach the speech discrimination level; that is, they are able to identify correctly short familiar sentences on auditory basis only (48).

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HEARING AID RESEARCH IN AUSTRALIA

H. Dillon
National Acoustic Laboratories, Sydney, Australia

ABSTRACT - Areas of hearing aid research currently being investigated in Australia include selection of appropriate gain and output limitation, design of aids to meet audiological specifications, earmold acoustics, assessment of aided performance, and investigation of advanced and unconventional hearing aid types.

RÉSUMÉ - La recherche qui se fait actuellement en Australie dans le domaine de l'assistance auditive concerne le choix des limites appropriées de gain et de rendement, la conception de prothèses auditives qui répondent à des spécifications audiologiques, l'évaluation du rendement avec assistance et l'étude de nouveaux types d'appareils d'assistance auditive perfectionnés.

Research into the design, fitting, and evaluation of hearing aids is performed in a few places within Australia, but this paper will comment almost exclusively on research performed within the National Acoustic Laboratories (NAL), which is part of the Australian Department of Health.

Hearing aid-related research performed by workers at NAL is largely geared to the needs of the hearing services offered by the organization. These services include the fitting of hearing aids and provision of necessary after care to children and eligible aged pensioners. In excess of 50,000 hearing aids were fitted in the past year, the majority of which were manufactured to NAL specifications by private contractors working under NAL supervision. The research described below thus influences all stages of the hearing aid provision process - from aid specification, design, and performance measurement, through to aid selection, fitting, evaluation and associated rehabilitation procedures. Conversely, these activities, especially the latter stages, provide the impetus for the research undertaken. The following areas of research are currently receiving attention.

1. Selection of optimum frequency response. The procedure in use within the hearing centres around Australia is the one developed at NAL by Byrne and Tonisson[1]. This procedure is aimed at amplifying all critical bands of speech to an equal loudness level, so that information in all frequency regions of the speech signal can contribute to the aid wearer's perception. The procedure includes an allowance for the shape of the average speech spectrum, the shape of the normal equal loudness contour at a comfortable listening level, and a term which increases the required gain at each frequency by 4.6 dB for every 10 dB of threshold loss at that frequency. Although the procedure has stood up quite well when compared to other procedures[2], additional validation and refinement is presently being performed by Denis Byrne. Although the results are still incomplete, they suggest that the present procedure makes a good estimate of the average gain required but may overestimate the response slope required, especially for very steeply sloping losses. It is possible that the discrepancy is partly caused by poorer frequency discrimination in the region of greatest loss. However, Denis' present study, in common with other studies, indicates a substantial correlation between frequency discrimination ability and threshold loss. Consequently, it is anticipated that an altered and more complex formula, but one still based solely on readily obtained threshold losses, will be able to improve the accuracy of prediction of the optimum gain versus frequency response.

2. Selection of optimum MPO response. Although it has received less research attention than the gain-frequency response question, selection of the appropriate maximum possible output (MPO) curve is also important. If excessively high output levels occur, then there is a danger of damage to residual hearing occurring, and there is also the possibility that the aid will be rejected because of the discomfort that accompanies the amplification of loud sounds. If the MPO is set too low, then the dynamic range of amplified speech will be unnecessarily restricted, with the probable loss of some speech cues. In aids without compression, this will also be accompanied by high levels of distortion. For aid wearers with a limited dynamic range of hearing in any frequency region, too low an MPO setting can cause amplified speech in that frequency region to be inaudible. Our research has identified a need for the MPO curve of hearing aids to be shaped, just as the gain curve is shaped, and this feature will be incorporated in future NAL aids. Two research programs presently under way are attempting to more closely specify the relationship between clinical measurements of loudness discomfort level (LDL) and the required MPO, and between MPO, LDL and hearing damage risk for various degrees of hearing loss. The first of these programs is using a computer

based wearable master hearing aid which pseudo-randomly varies the aid MPO at various times. At regular intervals, the subject records his reactions and sensations as he goes about his daily routine, while the aid monitors and logs such things as the noiseness of the environment, the volume control setting adopted and how often it is adjusted by the subject. The second program is making use of the known relationships between permanent and temporary threshold shifts, and the latter's rate of recovery after stimulation, to estimate a safe MPO level.

3. Hearing aid design specifications. NAL has on file an extremely large number of audiograms. As the frequency response selection procedure requires only audiogram information for its raw data it is possible to use it 'backwards' and predict what range of response shapes and slopes is required to cover any specified proportion of the hearing impaired population. This data indicates that, if the required slope within each octave is to be matched to within ± 3 dB, then 480 distinctly different response shapes are required to cover 95% of the population. When multipled by the number of different MPO shapes and levels which are required, it is obvious that to cover the required range, aids either have to be extremely flexible or else an immense number of them is needed. One requirement for the frequency response of aids which was revealed by the analysis, and which is met by very few aids, is the shape of the response curve below 500 Hz. Very few hearing impaired people require a sloping response below 500 Hz. It is possible that inclusion of a low frequency shelf in the response of aids may provide a way in which the quality of reproduction can be improved without an accompanying decrease in intelligibility.

4. Earmould acoustics. Work in earmold acoustics falls into two main areas. The techniques developed by Doug Fifield[6] for obtaining a mould with an air-tight seal are now used regularly in the hearing centres whenever leakage around the mold generates feedback and prevents the desired gain from being obtained. The research leading to this technique involved the introduction of materials new to the field of ear impression taking and the development of an appropriate method of combining these materials into the multi-(2 or 3) stage procedure. The procedure takes longer than a conventional impression but in the long run takes less time because it eliminates the need for subsequent impressions when the first has failed! The second area of earmould acoustics work has been carried out by John Macrae. This work has the aim of modifying the sound delivered to the earcanal in a variety of ways. By incorporating a cavity in the main sound tube within the earmould, a steep high frequency roll-off can be imparted to the aid's response[8]. This is particular useful for those cases where the hearing loss is greatest at around 2 kHz, with recovery of hearing in the higher frequencies. Alternatively, the cavity can be placed at the end of a side branch to produce a notch of controlled width and depth in the aid's response (useful for cases with 'islands' of hearing). In a second area of his work, Macrae has developed a vent incorporating a cavity which allows all the advantages of low frequency venting, but with a vastly reduced risk of feedback from high frequency sounds transmitted out through the vent[7].

5. Aided functioning. The topic of aided functioning is a multi-faceted one since the question "How much does a hearing aid help a person?" can be answered in a number of ways. Probably the simplest quantifiable improvement is in the change in threshold, or functional gain provided by the aid. Garry Walker and myself have conducted a series of experiments aimed at developing an accurate procedure for measuring functional gain in less than ideal acoustic environments[5].

The use of speech tests to help choose between one of two conditions, such as which ear or ears to aid has been studied in a generalized way. Theoretical considerations have indicated that if a test is to be maximally sensitive to the differences caused by different amplifying systems, then all items in the test should be equally difficult[4]. This is in marked contrast to most existing tests which usually contain several very difficult and several very easy items. The question of the success of a hearing aid fitting has been looked at more globally by Laurie Upfold using the results of a nationwide survey conducted by the Australian Bureau of Statistics and by analysing battery consumption figures and questionnaire data[10]. The survey, in 1978, indicated that aid usage in Australia was about the same as in the rest of the world, with a little over 50% of owners making consistent use of aids. In the following 3 years battery consumption per aid increased by 50%. During this period, no changes were made to the aids themselves, but the Byrne & Tonisson prescriptive aid selection technique was introduced to hearing centres, audiologists were given greater in-service training, and follow-up appointments for clients received greater emphasis. At least one of these factors appears to be related to satisfaction with amplification.

6. 'Other' hearing aids. Research and development effort has also been put into less conventional types of hearing aids. An FM induction field wireless system has been developed for use by hearing impaired children at school and at home. The transmitter and receiver pair incorporates a voice operated switch so that when no signal is being received by wireless, the child's aid reverts to picking up the acoustic signal around it. Research is also being directed towards discovering what processing can usefully be performed in a multi-channel aid. The first series of experiments revealed that when all frequency channels are operating in a compression mode, then the spectral flattening that occurs for many phonemes leads to a decrease in speech intelligibility. When the high frequency bands operate in the expansion mode, then low level consonants are greatly attenuated in level and intelligibility again

decreases. In a second series of experiments, we are attempting to combine the dynamic range reduction advantages of wideband compression, with within-band expansion aimed at increasing rather than reducing spectral contrasts. Another type of non-conventional 'hearing' aid being investigated is the vibrotactile aid. Geoff Plant has developed a training procedure for people fitted with presently available single channel vibrotactile aids, which are now issued regularly by NAL when appropriate[9]. With sentence type test material the results for single channel aids have been generally as promising as those of other workers using multi-channel devices. Geoff is presently investigating to what extent the suprisingly good-performance of single channel devices, when combined with lipreading, is due to their ability to transmit supra-segmental information through fundamental frequency and envelope amplitude cues.

The last area of non-conventional hearing aids being investigated is that of cochlear implants. These are not being studied by NAL but by a group at the University of Melbourne under the direction of Professor Graeme Clark[3]. The implant uses multiple channels driven one at time by a processor which extracts both fundamental frequency and a spectral peak in the 800 Hz to 4 kHz region, which will often correspond to the second formant. Psycho-physical studies indicate that subjects are able to discriminate between the different electrodes. When aided by lipreading, some subjects are able to score as highly as 75% on a 12-item closed set consonant tests, and as highly as 95% on an 11-item closed set vowel test! These results offer great promise for the profoundly impaired.

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SPEECH PROCESSING FOR THE HEARING IMPAIRED

Louis D. Braida
Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, MA 02139

ABSTRACT - Recent studies of speech processing for the hearing impaired are reviewed. In general the processing schemes are concerned with matching speed to the reduced auditory area of the impaired listener (e.g. amplitude compression and frequency lowering), with overcoming degraded resolution and distortions within this area, or with enhancing speech degraded by noise and reverberation.

RÉSUMÉ - On passe en revue les études récentes dans le domaine du traitement de la parole pour les malentendants. En général, les systèmes de traitement cherchent à apparier la parole à la zone d'audition réduite du malentendant (p. ex. la compression de l'amplitude et l'abaissement de la fréquence) en surmontant la résolution altérée et les distorsions dans cette zone ou en amplifiant la parole altérée par le bruit et la réverbération.

Introduction

Speech perception is often seriously degraded by sensorineural hearing impairment. Theoretically there are two distinct aspects of the loss which impede communication. First, the residual auditory area is often reduced so that the range of intensive and spectral variations available to convey distinctions between speech sounds is restricted. Second, the ability to resolve intensive, spectral, and temporal differences within the residual auditory area is often seriously reduced. Taken together these factors imply a reduction in "channel capacity" and hence a reduced ability to communicate via speech. This paper reviews a number of speech processing techniques which attempt to restore cues for phonetic distinctions degraded by the hearing loss, or introduce new cues that serve similar functions and that can be learned through training. While most previous work in this area has been concerned with acoustic aids, many of the techniques considered are also potentially applicable to tactile aids and cochlear-implants. Such devices are currently rather limited in the extent to which they convey highly intelligible speech. Independent of whether a listener's limited speech reception results from a partial natural impairment or from a very severe natural impairment that has been partially alleviated by the use of electrical or tactile stimulation, one is still faced with the basic problem of developing signal processing techniques to match speech to residual sensory function.

To date most forms of speech processing for the hearing impaired have focussed on the problem of matching speech to the reduced auditory area of the impaired listener (e.g. Braida et al., 1979). Linear amplification, addressed to the problem of reduced sensitivity and included in most hearing aids, is reviewed by Picard (1984). Two other forms of speech processing addressed to the matching problem, amplitude compression (for persons with reduced dynamic range) and frequency lowering (for persons with negligible hearing at high frequencies) are discussed below. By contrast, the problem of compensating for degraded resolution within the auditory area has received far less attention. Recent studies of the effect of speaking style on intelligibility suggest that it may be possible to overcome some of these degradations with signal processing, and some initial attempts will be discussed. A final form of signal processing to be considered is concerned with aiding the impaired listener by minimizing the effects of interference on the speech signal.

Amplitude Compression

Many sensorineural hearing impairments are characterized by reductions in both absolute sensitivity and dynamic range. Whereas linear amplification is addressed to the problem of elevated thresholds, amplitude compression, a form of nonlinear processing, is concerned with reducing the range of speech level variation to match the reduced dynamic range of the impaired listener. (Dynamic ranges for electro-cochlear and tactile stimulation are also much smaller than for normal auditory stimulation). Three distinct amplitude compression functions, with different level-temporal characteristics, have been studied. Automatic volume control (AVC) is a relatively slow acting form of compression which serves to control relatively long-term variations in speech levels. Syllabic compression is intended to reduce the level variations that occur within and between syllables. Limiting is a very rapid form of compression intended to protect the listener from sounds intense enough to cause discomfort or pain.

Most recent research on amplitude compression has attempted to employ syllabic compression to improve intelligibility for impaired listeners. Although Villchur (1973) reported substantial advantage for a two-channel compression system over linear amplification, subsequent studies (e.g. Abramovitz 1979; Lippmann, 1981) failed to confirm this result. In particular, Lippmann (1981) found Syllabic Compression no better than linear amplification with high-frequency emphasis appropriate to

the impairment. Recent studies (e.g. Braida et al., 1982, De Gennaro et al., 1984) suggest that listeners with moderate hearing impairments may derive as much benefit from linear amplification combined with appropriate forms of AVC and Limiting as from multiband syllabic compression, but that some listeners with very severe impairments may benefit more from syllabic compression. Recently, Laurence et al. (1983) found that a wearable hearing aid with both AVC and two-band Syllabic Compression provided superior speech intelligibility for impaired listeners in both quiet and noise relative to a "high-fidelity" aid which did not include AVC.

Several recent technical studies have been concerned with improving the signal processing in syllabic compressors. De Gennaro et al., (1981) have shown that conventional compression amplifiers have only limited ability to reduce the dynamic level variations in speech. Hendrickson (1982) reported modest improvements in intelligibility for impaired listeners using a novel wideband compressor suggested by Robinson and Huntington (1973). Analytical studies generally indicate that multiband compression can improve the salience of acoustic cues for manner distinctions, but often degrades those for place distinctions within a manner category. Bustamante et al. (1984) suggest that this results from reduction of spectral detail by the independent action of multiple compressors, and report that inter-band control of compressor action can reduce speech level variations while preserving spectral difference cues.

There has been relatively little systematic study of compression limiting although hearing aids must clearly incorporate processing to protect the impaired listener from amplified sounds capable of causing discomfort. A recent study by Abramovitz (1979) indicates that compression limiting is superior to simple peak-clipping in terms of inteligibility. A multi-band limiting system studied by Bustamante (1981) yielded higher average intelligibility than a linear amplification system when the overall level of speech varied significantly. Evaluating limiting is likely to require a better understanding of the trade-offs between intelligibility and protection from intense sounds that are acceptable to impaired listeners. Such trade-offs are very difficult to establish in laboratory settings.

Frequency Lowering

Frequency Lowering, addressed to the problem of severely degraded hearing at high frequencies, transforms high-frequency speech elements to the lower freqencies where hearing is often less impaired. A wide variety of frequency lowering techniques and degrees of lowering have been studied. Most have been derived from speech bandwidth compression techniques, rather than designed with the perceptual needs of the impaired listener in mind. Few have been evaluated carefully, and many of the evaluations have been strongly deficient with respect to the obvious need for training in the use of recoded speech cues. As a result the true potential of frequency lowering is largely unknown.

Two techniques have yielded modest benefits for impaired listeners. One, based on a technology used by the blind to listen to recorded materials at increased rates (Mazor et al., 1977), has been shown to yield small but consistent improvements in intelligibility (particularly for female speech) using only moderate amounts of frequency lowering (20%, corresponding roughly to the difference between male and female formant frequencies). In the other, low frequency surrogates for high frequency speech elements are introduced over unprocessed low-frequency speech elements by modulation. Although slightly different processing techniques were employed, both Lippmann (1980) and Velmans (1982) report that this approach yields increased intelligibility for high-frequency speech sounds.

Recent work by Reed et al. (1983) provides some insight into the problem of improving intelligibility with large degrees of frequency reduction. The speech processing scheme used altered the short-term spectral envelope but did not affect fundamental frequency. Two bandwidth reductions (from 5000 to 1667 and 1000 Hz) and several spectral transformations were studied. Discrimination tests of listeners with normal hearing using nonsense syllables showed no net advantage for frequency lowering relative to low-pass filtering to an equivalent bandwidth. The best results for frequency lowering were obtained with nonuniform spectral transformations which altered low-frequency components relatively little, but compressed and lowered high frequency components a great deal. Detailed results indicated superior item-pair discrimination in cases where detection or discrimination of high-frequency components was a key factor, but degraded discrimination when low-frequency components were important.

Frequency lowering may never be fairly evaluated in laboratory (or classroom) settings since relatively long-term use is required for the impaired listener to learn transformed speech cues. Low-pass filtering and other degradations of high-frequency speech elements occur in many common acoustic environments. Many impaired listeners with severe high-frequency losses have adapted to the loss of speech cues provided by high-frequency sounds. Evaluations which provide "equal" exposures to frequency lowering and "control" conditions may substantially underestimate the extent to which transformed speech cues can be learned.

Distortions within the Auditory Area

Relatively few attempts have been made to compensate for reduced resolution or distortions within the auditory area (e.g. reduced frequency selectivity and recruitment). For example, Martin and Pickett (1970) have shown that at the high sound levels at which the severely impaired listen to

speech, the first formant of vowels reduces the discriminability of transitions in the frequency of the second formant. High-frequency emphasis can reduce this problem if the dynamic range is large enough. An alternate means of reducing the masking effect involves dichotic presentation of low- and high-frequency sounds (e.g. Haas 1982). To date, however, only minor benefits have been reported for this approach.

Most previous research directed towards improved speech intelligibility for the impaired has focused on the signal processing of conversational speech. Thus, the extent to which limitations on intelligibility are caused by speech-processing inadequacies as opposed to impaired auditory function, is unknown. However, recent studies have shown that it is possible to create more intelligible speech for the hearing impaired by instructing speakers to talk more clearly, thus bypassing the processing constraint. This approach permits substantially increased understanding of the intrinsic limitations to be obtained, and it offers the prospect that improved speech processing techniques can be developed by determining the acoustic differences that underlie the improved intelligibility and constructing signal processing schemes that focus on these differences.

Picheny (1981) tested impaired listeners on words in nonsense sentences spoken both "clearly" and "conversationally" and analyzed the acoustic differences between these two types of materials. Materials were presented to five impaired listeners at three intensity levels using two frequency-gain characteristics. Test results showed a clear and robust intelligibility advantage (17 percentage points) for clear speech. Substantial improvements were obtained for essentially all listeners, all frequency-gain characteristics, all (three) speakers, and all levels. In addition, the improvements appeared to be roughly independent of word position in the sentence and phoneme class. Acoustic analysis indicated that there were large differences in the temporal characteristics of the two types of materials. In clear speech, the speaking rate was reduced by roughly a factor of two; and significant increases were observed in the number and duration of pauses, the duration of most speech sounds, and the range of fundamental frequency variation. Analysis of phonetic characteristics showed no substantial change in long-term spectra, a non-uniform increase in consonant-to-vowel amplitude ratio and a variety of changes in individual consonants and vowels. Similar results have been obtained for stop consonants in nonsense syllables by Chen (1980).

Research on the effect of "speaking clearly" has demonstrated that there are acoustic differences which can yield consistent gains in intelligibility for the hearing impaired. The extent to which such improvements can be achieved with speech processing is currently being studied. For example, Ono et al. (1982) and Harasaki et al., (1983) reported substantial gains in recognition accuracy by impaired listeners for voiceless-plosive and nasal consonants processed to achieve acoustic differences similar to those found by Picheny (1981) and Chen (1980).

Signal Enhancement

Many impaired listeners report great difficulty communicating in the presence of background noise and/or reverberation. Current approaches to this problem employ detachable (remote) or directional hearing aid microphones, or multiple microphones, (e.g. certain "CROS" hearing aids). Although a wide variety of speech enhancement systems have been suggested for persons with normal hearing (e.g. Lim and Oppenheim, 1981), relatively little success has been demonstrated in published evaluations. Many of the systems studied improve signal to noise ratio, which is generally perceived as an improvement in speech quality, but almost all the systems fail to improve intelligibility. Some of these schemes may nevertheless prove beneficial to the hearing impaired, who appear to lack normal abilities to process degraded speech.

One approach which deserves increased attention seeks to restore the directivity functions provided by the binaural auditory system to those whose hearing impairment degrades these functions. Plomp (1977) and Zurek (1983) have shown that normal listeners derive roughly a 5 dB advantage in signal-to-noise ratio from binaural processing in anechoic environments when speech and interference are spatially separated. Such an improvement is likely to be highly beneficial under the marginal listening conditions characteristic of many everyday situations. Currently used techniques generally do not attempt to restore the normal binaural advantage.

Conclusions

The prospect that speech processing may help alleviate some of the handicap associated with sensorineural hearing impairment is relatively promising. Studies of the difference between "clear" and "conversational" speech suggest that it may be particularly fruitful to attend to the temporal characteristics of speech. In addition, preliminary studies suggest that certain amplitude compression and frequency lowering techniques may be beneficial for the impaired. Important opportunities exist for preprocessing speech to enhance its intelligibility by reducing the effects of interference and reverberation.

Although advances in digital signal processing have made it possible to simulate a wide variety of speech processing schemes on a laboratory computer (the present day master hearing aid), many forms of processing require evaluation in the "real-world." Future research will increasingly require economical wearable prototypes of speech processing schemes for such studies. Ultimately, the problem of alleviating the effects of hearing impairment will require an iterative process in which a promising speech

processing scheme is implemented, its performance measured, success evaluated, and failure understood in order to improve the scheme or to point the way to alternative approaches.

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SENSORY AIDS FOR THE DEAF: VISUAL, TACTILE, AND ELECTRO-AUDITORY

J.M. Pickett
Rehabilitation Engineering Center, Gallaudet College, Washington, D.C. 20002

ABSTRACT - A review of current research and development for electronic devices to aid speech communication for the deaf via visual and tactile displays, compared with electrical stimulation of hearing.

RÉSUMÉ - Une étude de la recherche et développement actuels en matière de dispositifs électroniques pour favoriser la communication des personnes sourdes par la parole grâce à des écrans visuels et tactiles. On compare avec la stimulation électrique de l'ouïe.

This paper reviews recent results in research on aids for the profoundly deaf. Work in this field concentrates on speech communication, the most crucial problem affecting the education, vocations, and acculturation of the deaf. Persons deafened very early in life, before learning to speak and understand, fail to develop easy speech communication. Lipreading is a highly unreliable way to perceive speech messages and the speech of most early-deafened deaf persons is not effectively intelligible. Aids using visual presentation of speech information have been developed for speech-feedback in voice training as well as for aiding speech reception. Tactile aid development has focussed more on reception. Auditory implanted electrodes provide a very rudimentary form of hearing via surgical approaches to the inner ear (cochlea). A detailed history of all these developments will be found in Levitt et al. (1980). Current work is summarized here and comparisons are drawn between tactile and electro-auditory aids.

Visual Aids. The most advanced visual speech aid, called the Autocuer, has been developed and pretested with trained deaf viewers at Gallaudet College (Cornett et al., 1977). The Autocuer uses a 16-channel spectrum analyzer on a microchip to analyze and classify incoming speech sounds. It picks out the vowels and consonants in the speech stream and pairs a consonant with the vowel that follows it, establishing a partial syllable as the recognition unit. The system does not attempt to identify the syllable precisely--this is beyond the capability of current wearable speech-recognizers--but it does identify a category of nine syllables to which the syllable belongs. The system flashes a symbol representing the category via eyeglasses worn by the lipreader. Given this clue to the category-class of the syllable being spoken, the viewer can usually decide which syllable was actually spoken from the speaker's lip and tongue movements, which are viewed concurrently through the eyeglasses. Results of 80 to 95% correct under simulated reception have warranted a program of field tests scheduled to begin this year.

Electronic displays of speech acoustic patterns have been adapted to teaching the deaf to produce more-intelligible speech. The complete time-varying spectrum of speech may be displayed on a video monitor, as in the speech spectrographic display by Spectraphonics Inc. in Rochester, New York. The instant spectrograms of the display are being tested at the Rochester School for the Deaf and the National Technical Institute for the Deaf, a division of the Rochester Institute of Technology, Rochester, New York, to train deaf students to speak.

Instead of displaying all of the speech spectrum, workers at other research centers have built indicators of particular acoustic features, such as the fundamental voice frequency, the intensity envelope, the general shape of the spectrum, and/or the presence or absence of energy in a given spectral band. One group of acoustic researchers at Bolt Beranek and Newman in Cambridge, Massachusetts, developed a children's computer-based speech-training system with displays that resemble video games.

Indicators of the positions and movements of the tongue and larynx are also under study as speech-training aids. An indicator may operate from the acoustic signal or more directly from the speaker's articulators themselves. An example is the artificial palate developed at the University of Alabama at Birmingham. The palate holds an array of electric contacts in the mouth and those touched by the tongue during speaking are indicated on a display. Thus a trainee can see how the tongue articulates, an important aspect of producing such consonants as t, d, s, and z, as well as such vowels as ee and ay (Fletcher, 1982).

Another articulation sensor is the Laryngograph, which monitors the impedance across the larynx between two plates held against the throat. The Laryngograph was developed and is being tested at the Phonetics Department of University College, London. The impedance varies in waveform with the degree of contact between the vocal folds, or vocal cords. The rapidly changing configurations of the contact between the folds

are correlated with voice characteristics. Thus the Laryngograph wave may be processed to yield a display of voice pitch, coordination of voice onset with the movements of the upper vocal tract, and possibly voice quality.

Some speech-training experiments use a speech-recognition system. Suitable speech patterns for recognition are stored in the recognizer for the trainee to attempt to pronounce. A deaf person sometimes pronounces a word or phrase very well, but most of the time does not, so the word recognizer is programmed with the more correct efforts and is used for feedback during practice to try to achieve consistently good speech. This concept is being tested at the Boys Town National Institute for Communication Disorders in Children, Omaha, Nebraska.

Tactile aids to speech reception. Tactile displays have been favored over visual, as aids to speech reception, because the eyes are often occupied with other tasks while receiving speech messages. However, the tactile sense modality is not as well understood as vision and may have limitations that often dictate concurent lipreading to obtain a useable level of communication (Loomis, 1981).

Tactile speech systems have frequently employed the "vocoder" approach. The "channel" vocoder derives a stream of spectral data using a bank of filters. The tactile display consists of a row of stimulators, one for each filter band, arrayed along the skin surface. The stimulation intensity of each stimulator is controlled by the sound energy detected in its filter-channel. Both vibratory and electrical stimulators have been studied.

Engelmann and Rosov (1975) studied the performance of a 23-channel vibrotactile vocoder in various word- and sentence-learning tasks with young adult normals and deaf children. A live speaker ("teacher") sat beside the tactile vocoder-wearing subject, with no lipreading. First only a small set of five words was used, spoken in isolation, until the subject could identify the words correctly, at first or after prompting, at a criterion level of success. New words were then introduced for further training until criterion was again achieved.

The tactile reception learning of four deaf boys was studied. The best subject (8 years old) achieved 80% correct (60 of a pool of 75 words) in a test after 34 weeks of training; he then accelerated his progress to achieve 90% correct (122 of a pool of 135 words) in 13 more weeks of training.

One deaf boy was trained wearing his hearing aid in addition to the tactile vocoder; he learned 35 words to 94% correct (tactile plus hearing) in 8 weeks. When tested with hearing only, he scored 65% correct, and 40% correct with tactile only, indicating that he had been able to integrate tactile with auditory information to identify among his first 35 words. At 21 weeks he achieved 90% of 60 words and at the end of 26 weeks he scored 78% of 100 words using his hearing aid together with the tactile aid.

Engelmann and Rosov concluded that "hundreds of corrected repetitions are required...to learn simple tactile discriminations" but that, given good learning conditions, the rate of learning will accelerate "once an initial set of 30 to 40 words has been mastered."

Brooks and Frost (1983) reported a study of learning to identify single common words presented on a 16-channel tactile vocoder. The subjects had normal hearing. Procedures were similar to those of Engelmann and Rosov. Daily sessions of about 1/2 hour were held five days a week, continuing to add 5-word sets to the training/testing pool. The subject with the most-extended training reached criterion on 150 words in 55 hours of training. With further training, 250 words were identified at 80% correct and the words were also found to be identifiable in sentences (Frost et al., 1983).

Thus it appears that tactile vocoders provide a limited but useable amount of speech information and that well-motivated training with systematic feedback procedures will enable tactile identification among a large set of words. Wearable tactile vocoders are not yet available, but development is under way to achieve wearability.

Two studies have recently examined the language behavior of very young deaf children with wearable tactile aids. Friel-Patti and Roeser (1983) carried out a study of the effects on communication by deaf children of wearing a tactile aid during class and therapy sessions. Four profoundly deaf children each wore a three-channel tactile belt for 10 to 11 hours per week for sixteen weeks of their Fall preschool semester. All children also wore hearing aids at all times. Every third week each child participated in an individual communication therapy session of ½ hour, during which a 10-minute video-recorded sample was made of each child's production of signed and spoken communication. These productions were analyzed as to duration, type, and content of communication. In the Spring semester, a no-aid condition was studied. The same procedures were carried out except that the tactile aids were removed and the children reverted to the use of hearing aids alone.

Over the Fall "tactile" semester, the duration of communicative productions from the children increased from a mean of about 1½ minutes per 10-minute sample to about 4 minutes. During the following Spring semester, with the hearing aids only, the duration of communication decreased from a mean of about 3 minutes to as low as 2 minutes per 10 minutes. Informal comments also indicated that the tactile aid had a beneficial effect on amount of communicative expression by the children. Teachers and parents spontaneously reported that it was "much easier" to elicit vocalization from the children when they were wearing the tactile aid.

Goldstein et al. (1983) reported that a deaf child who had only a five-word vocabulary at age three greatly increased her communicative attention when she was fitted with a wearable single-channel tactile aid. She then gained a 400-word vocabulary over the following seven months. This aid simply derived the rhythms of sound received and presented them on a single vibrator worn on the chest.

These two studies indicate that relatively simple tactile aids may provide an important increase in communication at a crucial period in the deaf child's education.

Electro-auditory implants and tactile aids. Auditory implants are electrode systems fixed surgically in a position to stimulate fibers of the auditory nerve (which are found to be stimulable in a very large majority of profoundly or totally deaf persons). Because such systems are not able to simulate the normal process of sound-to-neural conversion, the sound perceived from implants is highly abnormal. However, it appears that basic auditory rhythms and some low-frequency pitch information is perceivable by many implanted patients, even with only a single electrode. Multiple-electrode systems are under research to attempt to extend the range of useable frequencies. Presently the very modest amount of speech information provided by implants seems roughly comparable to that available through tactile aids (Pickett and McFarland, 1984). Let us briefly review some of these results.

A multiple-channel tactile system has been laboratory-tested using speech test materials similar to some of those used to test an Australian multi-channel implant system (Clark et al., 1983). The two sets of data offer the opportunity to compare advanced implant and tactile systems. The tactile aid was the Multipoint Electro-Tactile Speech Aid (MESA) of Sparks et al. (1979). MESA provided 36 channels of speech-spectral information to 36 tactile-stimulating locations arrayed horizontally along the abdomen. The Australian implant system employed 22 electrodes arrayed along a range of mid- to high-frequency fibers ending in the cochlea.

The speech tests were of two types: 1) consonant identification, and 2) tracking connected discourse (De Fillipo and Scott, 1978). Consonant identification was tested with closed sets of nonsense syllables that were listed for the subject. In the tracking test the speaker reads a simple story, phrase by phrase, to the receiver, who sits opposite lipreading and repeating each word or phrase just spoken; if the receiver is wrong on a word, the speaker repeats his utterance until the receiver gets it all correct. The measure of tracking success is the rate of advancement through the story in words per minute. For a reference rate: if the receiver is using normal hearing the rate is simply half the normal oral reading rate, that is about 220/2 or 110 words per minute (Scott et al., 1977).

The consonant reception of the implant patients, through the implant alone, averaged 41% correct; this was boosted to 69% correct with added lipreading. The MESA tactile subjects obtained 40% correct through the aid and 74% correct with added lipreading. Thus it appears that the basic consonant information available is similar in amount between tactile and implant aids.

In the tracking task the implantees averaged 36% of normal rate while the tactile subjects averaged 47%.

Detailed examination of the individual scores indicated that, unaided, the tactile subjects were much better lipreaders of consonants than were the implantees. Possibly this is because the tactile subjects were normal-hearing and were professional collaborators in the research and thus might be expected to be more language-test-sophisticated than typical implant patients. It should also be noted that, although the tactile subjects received consonants through the aid alone as well as did the implantees, two of the five subjects, did not significantly integrate feeling with lipreading. The other three subjects had more previous experience with tactile reception and made complementary use of both tactile and lipreading information.

There are some further results using word- and sentence-tests with a more-simple tactile aid developed at the Central Institute for the Deaf by Scott et al. (1977) and De Filippo (1983). These tactile results may be compared with the Australian implant results from Pyman et al. (1983). The tactile aid employed both electrical and vibratory skin sensations. In a two-channel mode, only the overall speech vibration intensity and the occurrences of high-frequency noise-like speech sounds (electrical) were provided. In a three-channel mode, information about the spectral spread over the high frequencies was presented via spread vs compact electrotactile sensations.

Considering first the implantees' performance in receiving monosyllabic words, only 8% were heard correctly through the implant alone but the implant information gave a large boost to lipreading the words, to 57% correct. The implant-aided lipreading of everyday sentences was highly successful (90 to 100% correct). The tactile subjects were not tested with the aid alone, but tactile-aided lipreading among a large set of monosyllabic words was 66% correct, somewhat better than the implant subjects. One of the tactile subjects was also similar to the implantees in aided lipreading of sentences, 93% correct. These data suggest that a relatively small amount of coded tactile information may have as much aid-potential as a relatively complex implant system.

From the point of view of the client, implant aids provide immediate sensations of hearing but entail major surgery and high associated costs. Tactile aids entail a learning period but are low-cost, easily replaceable aids. Both aids provide only a modicum of information which in some cases may be non-redundant. This suggests that further gains might be obtained with a hybrid system combining hearing implants and tactile stimulation.

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CODING OF SPEECH IN COCHLEAR IMPLANTS

M.M. Merzenich
Coleman Laboratory, UCSF, San Francisco, CA, USA 94143

ABSTRACT - The bases of coding strategies employed to represent speech in cochlear electrical stimulation prostheses will be reviewed. Device coders must incorporate information processing required to represent speech across a limited number of stimulation channels, and effect an appropriate translation between speech stimuli and patterned electrical activation of the axons of first-order auditory neurons.

RÉSUMÉ - On étudie les fondements des méthodes de codage utilisées pour représenter la parole dans les prothèses de stimulation électrique cochléaire. Les codeurs doivent être dotés de la capacité de traitement de l'information nécessaire pour représenter la parole par l'intermédiaire d'un nombre limité de canaux de stimulation et pour produire une traduction appropriée entre les stimuli de la parole et l'activation électrique structurée des axones des neurones auditifs de premier ordre.

Representation of speech by a multichannel cochlear implant prosthesis involves application of a speech processor-stimulator with two functional stages. In the first, speech information must be reduced in a coder which distributes information to a limited number of intracochlear electrode channels. In the second, stimuli must be shaped and scaled and distributed across multielectrode arrays to create an appropriate neural representation of speech sounds with applied electrical stimuli.

Most of the uncertainties and complications for developing and applying multichannel cochlear prostheses arise from this latter electrode-to-nerve interface problem. Uncertainties arise because: a) the normal basis of neural representation of speech across the auditory nerve array is still incompletely understood; b) it is not yet clear what advantages in speech representation result from use of a strict physiological-simulation strategy (e.g., all represented frequencies in representationally correct places and with distributed temporal discharge patterns simulating the normal); and c) it is not yet clear how to best avoid problems in channel interaction, which are to some extent unavoidable with stimulation of multiple channels of these relatively densely packed stimulating arrays.

The first requirement for any workable multiple channel auditory prosthesis is an electrode array with which stimulation across the auditory nerve array is really controllable. That is, the intracochlear stimulating array must provide for at least largely independent electrical stimulation control of a series of discrete sectors of the auditory nerve. From studies of channel vocoders which are designed to define the minimal information in speech required for its intelligible representation in normal hearing subjects and from studies of basic psychophysics, electrode arrays distributed across the speech frequency representational region of the cochlea with interelectrode separations of about 1 1/2 to 2 mm would seem to be necessary (and perhaps sufficient) to represent components of speech elements crucial for their recognition. With bipolar stimulation, studies in deaf animals indicate that largely independent stimulation of sectors of the nerve separated by these small distances can be effected, with ideally configured and positioned multielectrode arrays (1). Human studies have confirmed that finding, for a patient believed to have substantial survival of peripheral auditory nerve axons. However, in two other patients believed likely to have more limited nerve survival, spreads of stimulation appeared to be far greater, with excitation on any one channel extending broadly over neighboring channels at levels of stimulation required for implant operation. Such channel interactions are somewhat less when stimuli on nearby channels were applied non-simultaneously. Greater channel interaction is seen in these patients, probably because excitatory targets are further removed from stimulating electrodes.

Such studies suggest that there shall probably be two classes of patients for which somewhat different sound coders might be "ideal". In the first, peripheral axon survival is substantial; interactive effects are more manageable; and relatively high rate simultaneous or nearly simultaneous stimulation of electrodes separated by 1 1/2-2 mm is practicable. In the second, peripheral axon survival is negligible and ganglion cell loss great; interaction of nearby channels is consequently substantial; and non-simultaneous stimulation strategies will probably be required to minimize distorting channel interactions. For such device models, maximum rates of stimulation on any given channel would be lower.

Unfortunately, we do not yet clearly understand the costs re device performance of compromising the representation of components of speech elements by limiting stimulus rate, or by limiting or manipulating the patterned representation of speech in any one of several other ways. It has been argued that the spatial distribution of temporal information underlies the normal neural representation of speech elements. What features of the spatial distribution of temporal information must actually be simulated? We have demonstrated, for example, that we can generate a phase-locked representation of frequencies across the speech frequency range in restricted sectors of auditory nerve fibers. However, given place-(electrode-) specific percepts of "pitch" which are somewhat independent of stimulus frequency across most of this range, is it really necessary to represent higher-frequency stimulus periodicities? That question is still not clearly answered. Speech sound representations can also be translocated, and in several devices such translocations are employed because they magnify percepts of given speech components. However, we still do not clearly understand whether or not serious distortions result from such sound processor-to-nerve array representational translocations. Thus, the possible advantages of such artificial strategies for represntational emphases have not yet been weighed against their possible disadvantages.

Resolution of these interface issues have been hampered by several practical realities. First, electrode arrays do not extend across the speech frequency range in all applied devices, and those that do are substantially different in design. Second, for many cochlear implants, electrode arrays cannot effect spatial control of stimulation required to test these basic interfacing questions. Third, most applied devices allow for implementation of only a single coding strategy in any given patient, and patient performance has not usually been related to basic parametric psychophysical data in the same patients (e.g., to channel interaction measures). Fourth, speech recognition and discrimination test results in different patients with identical devices can be quite variable. Fifth, devices applied by different research groups differ in both their electrode-to-nerve interfacing and applied sound processors.

Sound processors for cochlear implants have applied several different coding strategies. Some investigators (including the UCSF and Utah-MIT groups) have attempted to implement a limited physiological simulation model (1-3). The sound processor employed by those groups is a baseband channel vocoder, with frequency channels set to correspond with stimulation channels exciting corresponding cochlear representational locations. Significant open speech recognition has been recorded in some patients stimulated with 3 and 4 channel devices of this type. Several other groups (in Vienna and Stanford) have obtained poorer speech intellibility scores with use of similar channel vocoders applied with interface translocations. However, whether that cause, or patient variability or other features of coding device design account for described differences in patient results is not known.

Two groups have tested formant extraction and representation schemes. Both involved frequency representation translocations. Promising results have been obtained with a representation of second formants by position and of the voice fundamental by rate, by the Australian group. On the other hand, with application of a more static formant extraction and representational scheme, the Stanford group has recorded near-chance performances in open speech tests.

Progress up to this time leaves little doubt that these multichannel devices can be improved. There are identified or expected sources of distortions in every device applied up to this time. It is clear that many of them can be overcome. Although there are inescapable problems in effecting a complete neurophysiological simulation of speech element representation with a stimulating array with a limited channel number, it now appears probable that at least most essential features of the neural representational patterns of speech elements are being appropriately reconstructed by some of these devices (4,5). The prospects for achieving high levels of intelligible speech in a large percentage of the totally deaf are real.

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TELECOMMUNICATIONS FOR THE DEAF

Denis Morrice, Executive Director
The Canadian Hearing Society, 60 Bedford Road, Toronto, Ontario M5R 2K2

ABSTRACT - The tremendous potential for developing communication aids for deaf people in the computer age is contrasted to the difficulty in the development and distribution of even the simplest device. The approach taken by the Canadian Hearing Society is explained in some detail with an eye toward future potential in computer compatible technical aids.

RÉSUMÉ - On met en évidence le contraste entre, d'une part, les énormes possibilités qui s'offrent à l'ère de l'ordinateur pour mettre au point des prothèses auditives et, d'autre part, la difficulté que pose la mise au point et la distribution d'un appareil des plus simples. On explique de façon assez détaillée l'approche adoptée à la Société canadienne de l'ouïe avec la mise au point de dispositifs compatibles avec l'ordinateur, en perspective.

We are growing into the electronic world! Of all segments of the population - deaf people stand to gain the most yet, historically, they have been neglected and discriminated against.

Hard copy information services provided by personal computers make it possible for deaf people to gain access to information and services they have been traditionally denied. In the past rapid information exchange has relied on use of the telephone, inaccessible to deaf people except through use of special telephones for the deaf. The computer revolution could open up a whole new world of communication to deaf people.

Up until now there have been tremendous difficulties in developing information networks and communication aids for the deaf. The development of TTYs and TDDs (telephones for the deaf) and signalling devices (wake up, door bell, telephone ring and baby cry) has been a most frustrating process for deaf people.

The importance of such devices for the deaf can be easily illustrated. Just imagine yourself at this conference unable to use the telephone in your room to call room service or the front desk; unable to hear a wake up call or even a knock on your door. Then think about living your whole life like this when it isn't necessary, because devices exist to let you use the telephone, hear the doorbell and use an alarm clock. The only problem is that no-one has put the time, energy and money into making these devices available to you.

Up until recently there were no CSA approved signalling devices, no Canadian made couplers or reliable portable TDDs. Hard to believe in the era of space age technology that even such relatively simple devices were denied to deaf people. Today there are many countries without such basic devices and, worse still, some people have dangerous make-shift signalling devices that entail 110 volts being connected to the door bell. Shocking isn't it!

What is the reason for this? One might ask, where have all the bright engineers gone. For many years there have been few, if any, engineers devoting time to the development of such technical aids. This is directly related to the second problem; the unwillingness of large manufacturers to enter this field, due to the limited market. As a result, the task has fallen on the shoulders of under-capitalized small manufacturers who often cannot survive, leaving deaf people in the lurch with aids that cannot be repaired.

For a long time there were no professionally Canadian-made devices, forcing us to rely on imports. Custom and exchange rate problems added to lengthy delays for repairs and made importing an unfeasible solution. The final problem is the difficulty in marketing to a segment of the community traditionally isolated and "cut off" from marketing techniques.

In the face of these obstacles, the Canadian Hearing Society has developed an approach to provision of technical aids which I would now like to share with you.

Because of our mandate as a major social service agency in Canada working with deaf and hard of hearing people, the CHS Board of Directors decided that technical aids would be a major service priority. The following steps were taken:

1. Commit CHS at a board and staff level to the development and provision of technical aids.

2. Hold open forums attended by deaf people to clarify technical aid needs.

3. Contact and obtain the commitment of a creative engineer.

4. Assist the engineer in procurement of National Research Council, R & D money.

5. Obtain funding for a Technical Aids Department in CHS.

6. Hire a deaf person to direct the programme and interface with the engineer and the deaf consumer groups.

Through the above we have been successful in the development of:

Optic Ear 1 - an inductive pickup signalling device for the door bell, door knock and telephone ring.

Optic Ear 3 - an acoustic pickup baby cry and wake up signaller.

TDD-COM.I - 20 character LED baudot code

TDD-COM.II - 20 character LED baudot and ASCII code and 3 200 character memories and a 1400 character main memory.

And are presently developing:

Optic Ear 2 - a wireless remote to work in conjunction with the Optic Ear 1.

Coupler - designed for both baudot and ASCII

TDD-COMPRINT I - 20 character LED and print baudot code

TDD-COMPRINT II 20 character LED and print baudot and ASCII code with 3 memories 200 character and a 1400 character main memory.

TDD DIRECT CONNECT Allows TDD to be plugged directly into wall jacks, by-passing the need for acoustic coupler.

TDD AUTO ANSWER Built-in answering modem receives messages when the user is not at home.

The future of deaf communications systems is computer like in nature, but at present incompatible with the actual computer systems in use. There are thousands of TTYs and TDDs in use that use the baudot coding as the protocol and this should not be abandoned. The present baudot coding system must be incorporated in any new system for a long time to come. The new portable TDDs are taking over the market. They are affordable and are designed for the deaf person. Although we are taking advantage of computer electronics, we are not taking full advantage of the electronic communications systems.

To provide deaf people with the opportunity to plug into the "electronic world" the following points must be satisfactorily addressed:

AFFORDABILITY: As a modern communication tool and one of basic necessity for a deaf person it must be affordable.

COMPATIBILITY: To ensure continued communication with the existing system and move with future technology, the system must be compatible with both baudot and computer networks.

PORTABILITY: Because it is an essential communication tool for the deaf person, the terminal must have battery powered capability for travel (pay phones, emergency, etc.) thus allowing the deaf person complete mobility.

MEMORY: Although a clear LED readout is usually a functional system, it still has the "now you see it, now you don't" effect. The memories are necessary for important messages, long distance calling, emergency records to be transmitted at the touch of one key.

PRINTER: The addition of the "hard copy" has the obvious advantages of clearer communication, easier response to a number of points made in a conversation, record keeping, etc.

DIRECT CONNECT: This allows the terminal to be plugged directly into the "phone jack" thus by-passing the telephone handset. Therefore, the terminal can be used as an answering machine with messages being stored for future playback.

The TDD that I am showing you today has addressed the above criteria for a good telecommunications aid for deaf people at this time. It was developed through the collaborative efforts of CYBERTECH INC., THE NATIONAL RESEARCH COUNCIL, and THE CANADIAN HEARING SOCIETY. This TDD is a major effort to allow deaf people to tap into the "electronic world". This TDD has been designed to address: the new Envoy 100 Communications facility being offered by Bell Canada; the automatic answering service; networking; bulletin boards; mailings; and message storage for later recall.

We feel we are on the road to the future. However, much effort must be expended to stay on this road and very serious problems must be confronted. Most noteworthy is the whole issue of telephone standards which includes the actual physical shape of the handsets down to all the technical standards of magnetic field outputs, etc. We have a big job to sensitize government policy makers, telephone companies, manufacturers of telephones that deaf people are not second-class citizens.

It would be a shame to see history repeat itself. Alexander Graham Bell invented the telephone while trying to invent a technical aid to assist his deaf wife. The telephone became one of the biggest barriers to deaf people in a world that lives by communications. We have now arrived at another stage in computer telecommunications that will affect deaf people more than any other segment of society. Let us hope that through creative engineering and sensitive policy makers we make this a positive experience for everyone.

SPECIAL SESSION/SÉANCE SPÉCIALE 7

VOCATIONAL REHABILITATION/

RÉADAPTATION PROFESSIONNELLE

Co-chairpersons/Co-présidents:

P.J. Nelson
National Research Council Canada
Ottawa, Canada

D.C. Symington
Queen's University
Kingston, Canada

THE IMPACT OF TECHNOLOGY ON VOCATIONAL REHABILITATION

K.-A. Jochheim and E. Mittelsten-Scheid
University of Cologne Rehabilitation Centre, Cologne, F.R.G.

ABSTRACT: In European countries, vocational rehabilitation has gone through many changes, especially in this century. In the future disabled persons should have more material independence because of new systems for matching jobs with abilities and because microprocessors are changing the nature of jobs for everyone.

RÉSUMÉ: Dans les pays européens, la rééducation professionnelle a subi de nombreux changements, surtout au cours de XX^{e} siècle. À l'avenir, les personnes handicapées devraient jouir d'un plus grande indépendance matérielle par suite de l'existence de nouveaux systèmes d'association des emplois et des aptitudes et parce que les microprocesseurs sont en train de modifier la nature des emplois pour l'ensemble de la société.

Though the French Constitution of 1793 already includes the basic ideas of rehabilitation expressing the obligation of the society to provide adequate work for disabled citizens or alternatively the necessary means for survival, the impact of industrialization and the major alterations in social policy are closely linked around the change of our century. With a few earlier models for blind and deaf children the main initiative arose from the fact that urbanization had split the grand family and one generation alone was usually unable to provide adequate services for disabled children.

The new medical discipline of orthopedic surgery took world-wide the leadership establishing institutions providing joint services of clinical medicine, schooling and vocational training under one roof.

Cooperation between those national societies for the welfare of cripples formed the basis for our present well-known society Rehabilitation International.

In the first industrial revolution societies apparently had to struggle with so many unsolved problems that charity organizations were looking for institutionalization apart from big cities to help their clients gaining sufficient maturity including professional skills for later reintegration.

The basis for vocational assessment has been mainly a selection of crafts with reduced demands on muscle power and endurance but with sufficient ability in manual dexterity and intellectual capacity. A few ergonomic designs were able to solve individual problems. The biggest group in these institutions were polio victims.

The first world war ended with a comprehensive initiative to provide complete rehabilitation services for war victims and utilizing the experience gained with crippled children and young adults for this purpose. Primarily for ex-soldiers developed legislation was gradually adapted to other applicants for workmen's compensation, pension insurance et al and thus broadened the eligibility for services neglecting the cause of the disability (casuality) and emphasizing needs without regard of the cause (finality). This trend was pushed forward during the second world war with the heavy demand from the labour market to compensate for those being under arms and has been continued in the last decades responding to demands or social security as a pronounced goal in developed societies regardless of the political orientation.

Technology in this period has tremendously influenced the programs in vocational rehabilitation. It has proved important to train disabled persons in a way that they are ahead of their co-citizens and therefore in the position to be hired even against able-bodied competition.

This urge has led to rather different systems of vocational training. In Germany we have used a considerable amount of tax money and social security contributions to provide nearly 20,000 places in institutions for vocational training programs between 1 1/2 and 3 years duration available in the main regions of the country. In Belgium, on the contrary, vocational training and retraining is mainly carried out in private industry, commerce and public services with reimbursement of expenses through a state agency. This way also had led to a full professional qualification or on a minor level to an on-the-job training. In most of the industrial societies a network of sheltered employment has been developed for those disabled citizens whose capacity does not fit anymore into the demands of modern production and business administration.

The rapid change of demands on the labor market due to implementation of modern technology into the production process, as well as administration and production control, increases the difficulties to provide all the basic knowledge and the skills to fill a position sufficiently. Muscle power and endurance are usually replaced by machinery and ergonomically supported by working aids, improving posture, mobility and transport, manipulation, communication and safety. On the other hand, comprehension of the work process, stress tolerance and responsibility in decision making and teamwork become increasingly important. Deficit in the intellectual and psychological capacity, therefore, have become much more dangerous for a personal professional success than any physical disability as such.

Aspects of future vocational rehabilitation

In our modern industrial society no job demands all abilities of a non-disabled person. On the other hand disabled people lack one or several abilities at a higher or lower degree. If one could find jobs demanding the remaining abilities only - and not demanding the reduced or missing abilities - it should be possible to find jobs for most disabled people where they could perform "normally" and earn their livelihood just as non-disabled people do - and become independent from public support.

The ERTOMIS-Foundation in the Federal Republic of Germany initiated a research project aiming at a practical solution to bridge the gap between information needed by the potential employer and the inappropriate information the rehabilitation client was able to present from a solely medical assessment.

The researchers defined a set of 62 criteria - called "Elementary Functions" = "Abilities" - selected from "WHO International Classification of Impairments, Disabilities and Handicaps" (Geneva, 1980). They modified them to become suitable for job analysis. The criteria correspond with all kinds of functional implications of impairments and disabilities - insofar as they have a tangible impact on the working ability. They are applicable to all kinds of jobs and to all kinds of disabled persons.

A classification by "Vocations" was generally in use for the description of "jobs" up to the end of World War II." "Job Evaluation" introduced in Europe around 1950 broke "Vocations" down by a more sophisticated analysis. As technology changed from "handycraft vocations" to "industrial vocations" physical strain was increasingly replaced by mental strain. Specialization, mechanization and automation were introduced increasingly as a means to compensate - at least partly - nominal wage increases in order to avoid price increases for the consumer - and to maintain competitiveness both nationally and internationally. Specialization and Work-Simplification reduced the scope of abilities demanded by a job and microprocessing equipment accelerates the changing of the nature of jobs.

Public interest turned increasingly to rehabilitation and reintegration of disabled people into productive employment. This would have been difficult with the demand for "old vocations". But the new approach via "analytic job evaluation" adopted by ERTOMIS could facilitate such reintegration. The System defines the "Demands" of a specific job - and the "Abilities" remaining to a disabled person by the same set of 62 criteria to be utilized. An appropriate job for a specific disabled person can be found by simple comparison of the two Profiles. Modification of the work-place could reduce the demands and special training or prosthetic help could increase his/her abilities.

If properly applied the System could offer new horizons for the material independence of disabled people of all kinds.

EMPLOYING SEVERELY DISABLED PERSONS IN COMPUTER-RELATED FIELDS

C. Gerald Warren, Clinical Associate Professor, Department of Rehabilitation Medicine, University of Washington, President, C. Gerald Warren and Associates, 4825 Stanford Ave., N.E., Seattle, Washington 98105

ABSTRACT - The use of computers is rapidly increasing opportunities for severely disabled people to enter competitive employment in the computer industry and in many applications areas. This paper presents guidelines to properly prepare and equip these people to take their places in this new generation work force.

RÉSUMÉ - L'utilisation des ordinateurs augmente rapidement les chances des personnes gravement handicapées de percer sur le marché du travail dans l'industrie de l'ordinateur et dans plusieurs autres domaines d'application. Cette communication présente des lignes directrices pour bien préparer et outiller ces personnes pour qu'elles puissent prendre la place qui leur revient au sein de cette nouvelle génération de travailleurs.

Introduction:

In computer trade publications, "new technological breakthroughs" are announced almost daily, rapid advances in computer technology predicted to continue almost indefinitely. "Man is a tool-making animal," said Thomas Carlyle (1775-1881). "Without tools he is nothing; with tools he is everything," a statement which is especially true for people who are severely disabled. While computers provide some increment of enhancement to the function of able-bodied people, for severely disabled people, the application of computer technology can represent the only way they may be able to enter mainstream employment.

The uses of the microcomputer in small businesses, in commercial applications, and in distributed processing are spreading rapidly. It is providing unprecidented career prospects for many people both in the industry that supports computer utilization and in those areas where the microcomputer is used as a tool to perform a wide variety of functions. Properly trained and equipped, severely disabled individuals can compete for the many new career opportunities the computer has made available.

People and Positions:

The computer industry and other industries which use computers provide a tremendous array of employment opportunities for physically disabled individuals. Not only does the computer provide an increased availability of high-paying jobs with reduced physical demand, but it also provides the opportunity to use microprocessor technology to substitute for functions that cannot be accomplished by severely physically limited individuals. It is precisely these severely disabled individuals who can experience the greatest incremental jump in functional capability, finding real opportunity for career development heretofor never available to them, if they are provided the technology to accomplish these tasks.

While employment within the computer field requires an education in some level of computer science, employment in many settings, where a microcomputer has been incorporated to accomplish specific tasks, only on-the-job training in computer literacy may be required. The concept of the paperless office strategically meets the needs of severely disabled individuals.

In the computer-related industry, entry level people often have a tremendous potential for upward mobility as the industry grows in size and applications expand. The most common entry level is at the commercial programmer level, where a person with one year of training in the fundamentals of COBOL can enter the field. Through continuing education and on-the-job training, they can rise to levels of analyst systems programmer, data base specialist, data communications programmer analyst, project leader consultant, manager of technical services, operations manager, computer systems director, sales manager, and technical support representative. With more specialized training in parallel fields, opportunitites are available as engineering/scientific programmers, software engineers, technical writers and editors. Positions are also available with less technical and creative demand in computer operations and technical support services, those positions which deal with the mechanics of using the computers and maintaining operations.

In the areas where microcomputer applications are being rapidly developed, employment opportunities are found in distributed data processing, office automation/electronic offices, communication services, information services, and in specialty applications in professional disciplines such as engineering, medicine, law, architecture, etc.

The software and hardware developments for personal computers that are literally exploding into the marketplace make it possible to consider the use of computers in nearly any field which can benefit from efficient use of data and/or rapid processing of information. Some areas in which this is already taking place are in accounting & finance, banking, manufacturing, brokerage, communications, computer products, distribution/marketing, hospital health care, insurance, wholesale/retail, engineering/scientific, operations research, printing/publishing, public utilities, transportation, computer-aided design, computer-aided manufacturing, distributed processing, graphics, office automation, etc. In any of these areas, an applications package can be purchased and operated by a disabled person.

Preparing the Person:

The process of preparing a disabled person to enter the job market varies considerably both with the individual's background and the placement objectives. Most commonly, the preparation to enter the computer industry targets on the position of an entry-level programmer. Generally, the qualifications necessary to enter a training program for entry-level programmers includes a high school diploma or G.E.D., above average intelligence (i.e. an IQ of 105 to 115), reading comprehension at the 12th grade level, and a score at or above the fiftieth percentile on the S.R.A. computer aptitude test.

Training can be accomplished through community colleges or business schools, or through programs especially developed to train disabled people in computer programming. Some 24 specialized programs have been in operation in the United States, serving a variety of people with physical disabilities, the vision and hearing impaired, as well as deaf and blind individuals (Ref. 1). Each of these specialized training programs is slightly different, based on different regional organizations. However, in general they have similar characteristics: They are usually sponsored, funded and administered by local agencies which may be state rehabilitation departments, independent rehabilitation facilities, community colleges, state universities or private, non-profit corporations. Secondly, most have a Business Advisory Council (BAC) which acts as the advisory and guiding body of the project, establishing the nature and quality of the program. This BAC shares the responsibility with the sponsoring agencies to place the graduates in competitive employment.

The council is made up of executive or data-processing managers or programmers from the major corporations of the region who are heavily involved in data processing as part of their companies' operations. Once established, this council is organized into committees which form the four or five major functions necessary to establish the program. They assist in hiring the instructors, selecting the students, establishing the curriculum, which usually fills a nine to ten month period, including the six to eight weeks on internship. The BAC becomes active in evaluation and technical review of the students' progress and course content. Later in the project, a placement committee is established which helps train the students in job search and retention skills while also assisting in their placement.

In these programs, experience indicates that regardless of the source of training for the disabled individual, a comprehensive approach must be taken to job readiness. Many of these people may have never worked, particularly in a professional capacity. They may not only need to be trained in behavior, proper dress, etc., but also in physical management of their disabilities when placed in competitive work situations. The training of severely disabled individuals is usually sponsored by a third party payer, which is most commonly a government agency, or occasionally an insurance company. The costs involved in training a severely disabled person are incurred in three basic areas: The first of these is establishing adequate independence in activities of daily living, mobility and transportation, to assure regular and functional attendance which can be carried through to the workplace. Expenditures can vary considerably according to the level of rehabilitation already achieved, however it can be a major cost that cannot be overlooked. The second area is tuition, which varies according to the source of training. In the specialized nine-month programs, however, this ranges between $6,000 and $8,000. The third area is the cost of adapting the environment in the classroom, and eventually at the job site, to assure that physical limitation is not the deciding factor in the person's achieving in the training program, or in being competitive on the job.

The application of a microprocessor (such as a personal computer) is a powerful tool for resolving many of the needs of severely disabled people who desire gainful employment. Supplying a computer involves a rather large expense when initiating a training program, and since there are many variables to be dealt with, this expenditure constitutes considerable risk for an agency. On the other hand, it is critical that the disabled person have every opportunity to perform classroom and computer terminal activities without his physical limitations significantly interfering with his ability to demonstrate that he can in fact become a computer programmer. During the program, benchmarks need to be established to enable the third party payer to assess the merit of allocating further resources to provide the higher levels of technology that will assure competitive employment. This incremental approach significantly eases both the anxiety of third party payers and the risks of high up-front costs. It is important to have the potential employer involved early in determining the availability of workplace adaptations. Very often, the responsibility for providing the basic equipment can be shared between the funding agency and the employer. The agency can then concentrate on providing the special applications hardware and software necessary to maximize the person's ability to operate the equipment. The most common physical problems encountered by persons in computer training are:

1. Being able to capture and record information which is provided in lectures and in meetings.

2. Accessing reference materials, books, manuals, input/output documentation.

3. Posture control for individuals who have decreased or no trunk musculature. For some, when they lift their hands to place them on a keyboard, their center of gravity moves sufficiently forward that residual muscles are often strained during prolonged activity, causing fatigue and pain, neither of which are conducive to effective concentration.

4. At the computer terminal, providing accessibility to the keyboard by the most efficient and least fatiguing means is the paramount consideration. Appropriate placement of reference materials and the screen may need attention as well, and if a person must use a single keystroke technique on some keyboards, there is a need to overcome simultaneous multiple key depression.

These general problems must be resolved for disabled people who are expected to use a computer productively. In most work settings there are many associated functions which may also need attention, such as telephone, intercom, dictation, security, signature, etc.

Physical Accommodation:

As Carlyle pointed out over a century ago, without tools, man can perform little; with them he can do almost anything. Properly equipped, severely disabled individuals can, with some assistance, be effective members of the work force and society as a whole. When preparing for work readiness, not only is it important to address the needs in the workplace; we need to assure that the individual is adequately supported in activities of daily living, mobility, transportation, and even in social leisure activities. The initial cost in equipping severely disabled individuals can be what appears to be extremely high. These expenditures need to be approached in a manner that allows one to assure that the investment is going to result in a successful outcome. Therefore, a plan needs to be developed whereby the expenditures can be incremented and tied to specific goal-oriented objectives.

In focusing on specific needs in training or employing severely disabled people in the computer industry or in applications areas, there are two basic considerations, first, solutions to physical tasks that cannot be performed generally in the workplace, and second, the use of software and a microcomputer to create a "toolbox" for a severely disabled person.

During the past 18 months, 20 severely disabled individuals have been successfully trained and placed in mainstream employment using computers in the Pacific Northwest. This was in part accomplished through C. Gerald Warren and Associates consulting for the Washington State Division of Vocational Rehabilitation. Most of these individuals were graduates of the "Project Entry" computer training program, which is housed at the Resource Center for the Handicapped in Seattle. In this training program, the problems which were listed above were addressed and resolved, to allow the students to complete their training and be placed as entry level programmers.

In the training program, independently capturing the information provided in lecture form was perhaps one of the most difficult problems, one which is often best resolved by having a note taker for all students and reproducing the lecture notes. The use of tape recorders has been found to be marginally effective, and is only slightly improved by the use of speech compression playback, which allows one to listen to the playback at twice or more the rate at which it was recorded. The second major obstacle was accessing reference materials: books, manuals, etc. It was found that most of the bound books needed to be disassembled and put into three-ring binders to be used on reader boards. Persons with no hand function used a mouthstick to manipulate the pages. In several instances, copy stands were used as well as articulated data holders and electronically operated copy holders. The electronically operated units used switch control of a line pointer, and one model scrolls the paper forward or reverse. These are very useful, particularly when dealing with 132 column printouts. Equipment is available for between $70 and $200 from data processing supply houses.

Posture control for people with limited trunk musculature is an extremely important issue to be resolved. For example, when quadriplegic individuals, lift their arms to operate a keyboard, the trunk center of gravity needs to be moved to the rear. To accommodate this need, since these people are usually not provided with reclining wheelchairs, small ramps are used to elevate the front castors of the wheelchair approximately 3 1/2 inches. This tilts the chair backwards sufficiently to provide better trunk balance, which significantly reduces the fatigue and resulting pain, facilitating prolonged activity at the keyboard.

To accommodate the needs of a majority of the people with limited or no hand function, it was necessary to be able to locate the keyboard with almost infinite adjustability within a two-cubic-foot space. No commercially available equipment was available to do this; therefore, we created a keyboard locator by mounting a camera tripod horizontally on ball joints and adapting the tripod head to carry the keyboard (Ref. 1). For people with limited arm and hand function this meant that we could place the keyboard low and close to them so that it minimized the amount of arm motion required to strike the keys. For people who had no hand function, the keyboard could be located optimally for use by short, lightweight mouthsticks. In each case, the screen often needed to be adjusted to maintain it in an optimum line of sight, particularly for those people who were performing mouthstick entry. Suspension data holders were used to position the printouts usually used for reference when inputing computer codes.

In several instances people who had either poor hand function or limited trunk stability were assisted through use of forearm rests, designed to allow the individual to place his forearms on a slanted surface which was effectively an extension of the keyboard. That function provided stability and increased accuracy and/or reduced fatigue. For individuals who were having difficulty with repeatedly changing visual fields, strategic positioning of the screen, copy holder and keyboard was of considerable aid to them. In instances where multiple keys had to be depressed to perform functions on the keyboard, spring clips were manufactured to catch the key as it was depressed and hold it down until it was released.

In the fifth or sixth month of such a program, a student will typically reach a benchmark such as completion of a COBOL workshop. At this point it is readily evident whether he/she will indeed pursue a programming career. This is when the application of more sophisticated technology should be considered.

The process of deciding on a microcomputer system to serve an individual's specific needs should be based on the following steps:

1. Making a clear and well defined list of the tasks that are to be accomplished.

2. Finding the software that will allow the person to perform the tasks defined.

3. Finding a computer system upon which the software will operate efficiently.

Obviously, the overlay on this process for severely disabled people requires a hardware system that can be adequately interfaced to the individual needs of the person.

The first and most important issue to consider when preparing a "tool box" for a severely disabled person is its flexibility and the degree to which it provides the person cross-industry mobility. The IBM personal computer line has become a de facto standard for the personal computer industry. Because of its dominance, there is currently more applications soft-

ware written for the IBM personal computer than for any other equipment in the world; there is greater communications cabability between PC's and mainframe computers, as well as an unprecidented number of computer peripherals. This is not to say that other personal computers that have specific applications capability should be disregarded. Apple, Digital, Epson and many other manufacturers have many specific applications packages available, but perhaps do not provide the versatility that would leave the maximum choice and mobility available to a disabled individual. There are also a number of IBM work-alikes in the personal computer marketplace, and indeed, many of these are adequate solutions. However, when the choice of equipment is made, we must address the question of longevity and true cross-industry compatibility.

Regardless of the specific applications capability of many other producers of personal computers, when we consider a young person's future being tied to a technology, it might better be risked with "Big Blue" (IBM) rather than with many other personal computers. The current equipment of choice is the IBM PC/XT, which with its hard disk, provides the greatest flexibility. The new XT370 and 3270-PC could be considered, but they are more expensive and perhaps not quite as flexible.

IBM's presence within the last year has brought about a surge of activity in rehabilitation R&D to develop personal interfaces to this equipment; the concept of a keyboard emulator for the IBM computer has received considerable attention. Development of keyboard emulators or transparent keyboards (i.e. methods of input which the machine recognizes as its own keyboard) is critical to giving disabled people access to the tremendous spectrum of software being developed. If we can trick the computer into thinking it is receiving information from its standard keyboard, then any software developed for commercial use on a personal computer is available to the disabled population. A keyboard emulator can take many forms. There are a host of communication devices which include row-column scanners, optical light-pointers, electro-mechanical keyboards and portable computers, all of which currently produce ASCII synchronous or asynchronous output. Currently there are protocol convertors under development to allow use of this type of equipment with IBM personal computers (Ref. 2 & 3).

A second very effective way of interfacing with this keyboard has been developed using sip and puff switching to operate Morse Code (Ref. 4), which creates a series of codes that will allow all characters or keystrokes on the IBM keyboard to be sent to the computer through specific dot-dash code. It also incorporates as the other emulators will, latching functions on the keyboard. This system is particularly powerful when it is combined with a product called PROKEY (Ref. 5). PROKEY is key-programmable software which allows one to create a set of key assignments and through one or two keystrokes, activate a host of functions in the computer. Each one of 137 keys or key combinations can have up to 1000 keystrokes internally assigned to them (Ref. 6).

A developing technology, which at this writing is in beta test, is a voice recognition system which truly emulates a keyboard. With this system, a person can speak commands which are inputed to the microprocessor as keystrokes from a keyboard. This technology, combined with the functional qualities of PROKEY, can create a system with somewhat more sophistication than the current Morse Code approach. By mid-1984, we will see release of systems which have speaker-dependent recognition with no limit of vocabulary and the capability of continuous voice recognition, which finds key words within spoken sentences. This can be incorporated into communications systems such as phone interfacing for auto-dial auto-answer, voice digitization which on command will store messages in verbal form or it can be used for voice mail. Voice-operated control of dictating equipment and basic elements of the environment will also be available. These developments are not being designed primarily for the disabled population. Their development is being driven by the industry's need to make the computer more friendly to the user. We can therefore be confident that it will be made available on the consumer market. When this takes place, it will surely benefit the disabled population to an even greater degree than those who use it for convenience.

Placement:

As previously indicated, the process of placement needs to begin as early as possible with full integration of line staff in the process necessary for integrating a disabled person into his work environment. There is no doubt that one of the greatest difficulties or barriers to placement is the employer's feeling of inadequacy and the fear of failing as an employer. Generally, within each organization capable of hiring someone with computer programmer or computer utilization capacity, there are people who are capable of becoming involved in applications technology which can be directed at assisting the disabled person. Finding those people in the organization, motivating them, and providing some early management support can be pivotal in placing disabled people in environments where they can become productive. Such placements can be extremely rewarding not only to the disabled person but also to those who provide them the opportunity to compete as an equal in the marketplace.

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REHABILITATION TECHNOLOGY - BREAKING NEW GROUND IN AGRICULTURE

W.E. Field, Associate Professor, Department of Agricultural Engineering,
Purdue University, West Lafayette, IN 47907, U.S.A.

ABSTRACT - The paper reviews the scope of physical handicaps, affecting agricultural producers and discusses the needs and resulting benefits of improved rehabilitation services to handicapped individuals living on farms. An overview of Purdue University's work in this area is also presented.

RÉSUMÉ - L'auteur examine la diversité des handicaps physiques touchant les producteurs agricoles et parle du besoin et des bienfaits de l'amélioration des services de rééducation des individus handicapés vivant à la ferme. Les travaux de l'université Purdue dans ce domaine sont également abordés.

INTRODUCTION

Historically, the concept of providing rehabilitation services to rural areas has been given a small amount of lipservice but not much else. The declining farm population, widely scattered locations of the rural handicapped, inadequacies or lack of health care facilities, limited economic resources, non-existent public transportation, and limited employment opportunities have compounded the traditional problems of service delivery. Farm families, especially, who are attempting to cope with physical handicaps often face barriers that differ significantly from those encountered by handicapped individuals living in suburban and urban areas. However, family based agricultural production with its diversity of qualities, appears to offer a much broader variety of occupational opportunities for the physically handicapped than might be anticipated.

The purpose of this paper is to briefly review the extent and nature of physical handicaps affecting agricultural producers and discuss the needs and resulting benefits of improved rehabilitation services to this population. An overview of Purdue University's work to increase the accessibility of essential agricultural tasks utilizing existing technology will also be presented.

EXTENT AND NATURE OF PHYSICAL HANDICAPS AFFECTING AGRICULTURAL PRODUCERS

United States agricultural accident data indicates that approximately 2 percent of the full-time farm operators and workers have suffered permanent disabling injuries due to farm-related accidents (Accident Facts, 1977 Edition). The Pennsylvania Agricultural Experiment Station found that 24 percent of the farmers under 60 years of age cited a physical handicap while 7 percent indicated that they suffered from a crippling handicap such as missing limbs (Fliegel, 1966). A study of 450 Vermont farm families discovered that approximately 4 percent of those interviewed reported leg or arm impairments including amputations (Tompkins, 1973).

A 1976 Purdue University study revealed that in a one year period, 1 member out of every 9 farm families was involved in a farm accident resulting in temporary disability and requiring medical attention (Field and Bailey, 1977). The National Safety Council has classified agriculture as the second most hazardous occupation in America (Accident Facts, 1982 Edition). Another summary, completed by the National Safety Council, of farm accident data from 21 states found that 64 percent of all farm work injuries were considered severe injuries (Hoskin and Miller, 1979). Approximately 1 percent of the farm injuries that occur each year prevent the farmer from continuing to farm (National Safety Council, 1981). Prior to the farm accident, 0.2 percent of the surveyed victims were physically handicapped whereas following the accident 1.9 percent of the farmers were reported as physically impaired (National Safety Council, 1981).

Figure 1. A variety of techniques are used to increase the accessibility of agricultural equipment. A paraplegic farmer uses this hydraulic platform lift to gain access to the operator station of his large agricultural tractor.

In addition to the disabling injuries caused by accidents, farmers and farm workers are also affected by other physical handicaps which restrict their ability to perform agriculturally-related jobs and participate in certain rural community activities. These include:

1. Cardiovascular diseases and disorders which limit lifting, climbing or extensive use of arms but allow tasks such as walking and driving (Morris, 1958). A health study of the general population conducted by the Indiana State Board of Health (1977) revealed "heart conditions" to be the most common handicap that prevents rural Indiana residents from fully functioning in their chosen occupation. Heart trouble was cited by 18 percent of the farm operators as being a disability or employment handicap in a 1973 Vermont University study (Tompkins, 1973). The National Center for Health Statistics (Series 10, No. 133, 1975-76) discovered that 14.8 percent of the adult farm population suffered from heart conditions.

2. Dust and mold allergies which make involvement in some agricultural operations, especially grain and hay handling, extremely uncomfortable or impossible without special respiratory protection (Ashley, Chan-Yung and Grezybowski, 1978). Dust was mentioned by 32 percent of Michigan's farmers as being a hazard to their health (Baker and Wilkinson, 1974) while 18 percent of the farm workers in an Idaho study perceived dust to be a major health problem (Bondy, Lebow, O'Malley and Reilly, 1976).

3. Back and spinal problems which are aggravated by heavy lifting, certain types of tractor seating and exposure to full-body vibration (Baker and Wilkinson, 1974). According to the Indiana Bureau of Safety Education and Training (Indiana Occupational Safety and Health Administration, 1979), lifting heavy objects was responsible for 11.9 percent of all the injuries that restricted a worker's ability to perform. Tompkins (1973) found that 29 percent of farm operators in Vermont indicated that they were suffering from back trouble. According to the National Center for Health Statistics (Series 10, No. 133, 1975-76) 9.3 percent of the farm population are limited in their work by impairments of the back.

4. Arthritis and other diseases of the joints which limit the range and ease of motion of fingers, arms and legs. A survey of 851 full-time Michigan farmers disclosed that 27 percent were hampered by arthritis (Baker and Wilkinson, 1974).

A study of Indiana farm operators completed at Purdue University in 1981 revealed that 30 percent cited musculoskeletal impairments, 25 percent indicated hearing impairments, 24 percent cited cardiovascular impairments, and 22 percent indicated respiratory impairments (Tormoehlen). Over 17 percent indicated that there were farm-related tasks which they could no longer perform because of one or more physical impairments. Over 19 percent reported that because of their physical impairments, they were hindered or limited in their ability to perform necessary farm-related tasks. In addition, 19 percent stated that they required assistance from a neighbor, employee, or family member to perform necessary tasks in their farm operation.

Figure 2. Presently, most modifications to agricultural equipment to accommodate the handicapped are locally made. This chair lift was designed and constructed by a paraplegic farmer.

COMPARISON WITH NON-AGRICULTURAL POPULATION

A comparison of general versus farm population data on the nature and scope of physical handicaps, suggests that the rural and farm population have a greater proportion of handicapped individuals. According to the President's Committee on Employment of the Handicapped (Facts about Handicapped People), 9 percent of the general population suffers from some form of physical disability. Other sources of data range as high as 17 percent. In comparison, the data available on the proportion of farm operators and farm workers who are handicapped suggests that between 15 and 30 percent are limited in their activities due to physical handicaps.

The National Center for Health Statistics (Series 10, No. 133, 1975-76) reported that 16.4 percent of the farm population experienced some limitation of activity due to chronic conditions whereas only 10.5 percent of the total labor force encountered such problems. Back problems appear to be more prevalent among the farm population as 17.7 people per 1,000 had displaced intervertebral disc compared to 13.5 people per 1,000 for the non-farm population (Series 10, No. 124, 1976). The farm population is more severely plagued by arthritis - 130.7 cases per 1,000 as compared with 109.2 cases per 1,000 non-farm people. (Series 10, No. 124, 1976). In addition, the National Center for Health Statistics (Series 10, No. 134, 1981) disclosed that a higher proportion of farmers are missing entire fingers or toes - 14.8 farmers per 1,000 versus 8.8 per 1,000 for the non-farm population.

The nature of most agricultural operations to be dependent upon family labor, leads many producers to remain on the job in less than good physical condition in the event of injury or sickness. The National Center for Health Statistics (Series, No. 133, 1975-76) found that the average days of bed disability per person per year is only 2.9 days for farmers compared to 4.8 days for the total labor force. A similar trend was also shown for other rural residents. Factors such as increased travel time to health care facilities, greater difficulty in obtaining walk-in treatment, and increased waiting time to schedule medical treatment can also result in minor health problems and or injuries developing into permanent disabilities (Sirvis, 1978).

NEED FOR EXPANDED SERVICES

A review of existing rehabilitation services in rural areas, in light of the previously described needs, suggests that there are many handicapped individuals living or working in agricultural production who could benefit from improved or expanded networks delivering independent living services and information. The impact of more effective delivery systems might include:

1. Previously unidentified individuals with physical handicaps living in isolated rural areas would be identified and directed to existing services and resources.

2. Handicapped individuals living in rural areas would become better informed of independent living services available to them and possibly become more willing to utilize them.

3. Rural leaders would gain greater sensitivity to the problems and concerns of the handicapped, hopefully increasing the level of community and citizen involvement.

4. Traditional attitudes that often restrict the employment opportunities of handicapped individuals in rural areas might be altered thereby increasing the freedom of career selection. For example; Does a farmer need to be free of physical handicaps to be successful? No, success in agriculture no longer hinges on human strength and labor but rather intelligent management.

BREAKING NEW GROUND PROJECT AT PURDUE UNIVERSITY

To assist physically handicapped agricultural producers who desire to remain actively involved in their farm or ranch, Purdue University's Department of Agricultural Engineering initiated a project designed to:

1. Determine the proportion of active agricultural producers who have physical handicaps.

2. Identify the types of physical handicaps which hinder active agricultural producers in completing essential work-related tasks.

3. Evaluate essential operating and servicing procedures on modern agricultural equipment to identify design factors which reduce or contribute to the barriers facing physically handicapped agricultural producers.

4. Develop, identify, and compile practical alternative designs, modifications, and accessories to aid physically handicapped agricultural producers in operating agricultural equipment and completing other farm-related tasks.

5. Establish a resource center designed to compile and distribute relevant information to physically handicapped agricultural producers and their families in order to assist them in remaining productive in an agricultural setting.

Initially funded by Deere & Company in 1979, the Purdue project has had contact with hundreds of agricultural producers with physical handicaps. A quarterly newsletter called "Breaking new Ground" has been developed. It is presently being distributed to approximately 2,200 individuals in North America, Europe and several countries in the Pacific region. In addition, 10 workshops attracting over 450 participants have been held in various parts of the United States to bring agricultural producers together who are attempting to farm with serious physical handicaps.

Figure 3. In some cases, hand controls are necessary to enable a handicapped farmer to safely and effectively operate modern agricultural equipment.

CONCLUSIONS

To date, the work-related rehabilitation needs of agricultural producers with physical handicaps have been generally ignored. The potential benefits of modern rehabilitation technology to many handicapped farmers has remained largely unrealized. In fact, little has been done to even accurately assess the scope of the needs which exist. The commitment of financial and technical resources falls considerably short of obvious needs.

However, encouraging steps are presently being taken by agencies such as the National Institute of Handicapped Research and United States Department of Agriculture to increase interest in rural rehabilitation issues. It is hoped that these activities will be expanded and supported with adequate human and financial resources.

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THE PARAPLEGIC FARMER IN MANITOBA

John Lane, Glen MacDonald, and Orville E. Olson
Canadian Paraplegic Association, Manitoba Division

ABSTRACT - Paraplegia is a devastating injury which severely restricts one's capacity to work at highly physical occupations such as farming. This paper examines some critical issues and discusses the role of the Canadian Paraplegic Association in Manitoba in providing support to paraplegic farmers.

RÉSUMÉ - La paraplégie est une sérieux handicap qui restreint considérablement la capacité d'une personne à effectuer des travaux demandant un grand effort physique, comme les travaux agricoles. Le présent rapport examine certains problèmes essentiels ainsi que le rôle de l'Association canadienne des paraplégiques en ce qui concerne le soutien apporté aux fermiers paraplégiques.

INTRODUCTION

One of the most debilitating physical disabilities is that of paraplegia*. Whether brought on by a severe traumatic accident or some insidious disease, the spinal cord injured person is left with loss of function in his lower limbs and in some cases impairment of his upper extremities as well. Other factors such as loss of bowel and bladder function, susceptibility to urinary tract infection and breakdown of the skin due to "pressure sores" further complicate the condition. A few decades ago the opportunity for a spinal cord injured person to lead a normal active life was very poor. Thanks to medical advances this is no longer the case as paraplegics can now look forward to a fulfilling lifestyle, including the opportunity to work in productive and meaningful occupations.

Farming is one of the oldest ways of life known to man. It too has advanced technologically, enabling farmers to produce crops and raise livestock in great abundance. Despite the high degree of mechanization, farming is still considered a very physical activity. It is demanding work requiring long hours, a high degree of mobility and a great deal of physical and mental stamina.

Given the type of challenges a farmer faces in his day to day operation of the farm and the limitations a paralyzed person is confronted with, how can a paraplegic farmer hope to continue in his chosen profession? After a lifetime of learning and living this way of life, which possibly many generations of his family have practiced, how can he give it up? To do so may not only entail a tremendous financial sacrifice but also threaten his entire identity which is totally immersed in and rooted to the land and the lifestyle. The fact is that many paraplegic farmers are operating their farms and are managing to do so successfully, despite the difficulties they face.

* Note:
When the term "paraplegia" is used in this paper it is meant to include the disability of quadriplegia as well.

THE CANADIAN PARAPLEGIC ASSOCIATION

The Canadian Paraplegic Association was formed in 1945 by paraplegic veterans who returned from the Second World War to a country which, although sympathetic to their needs, regarded them more as patients than as potential contributing members of their community. With the help of sympathetic friends and professionals, but always under the control of the paraplegic veterans, the Association spread quickly via the major veterans' hospitals across the country.

In 1946 the Central Western Division serving Manitoba, Saskatchewan and North-western Ontario was formed to represent C.P.A. from offices in Winnipeg. Other Divisions were centered in Toronto, Montreal, Vancouver and Halifax.

Since those early years the Association has become truly national in scope with Divisions in every province with the exception of P.E.I. The Central Western Division has been restructured along provincial lines to become the Manitoba Division and the membership base has shifted to become primarily comprised of civilian paraplegics. From its initial medical focus the Association in Manitoba has developed a professional organization with a staff of nine persons and a three-part program comprised of community advocacy, specialized information services and rehabilitation counselling.

THE MANITOBA EXPERIENCE

By Canadian standards Manitoba is an average-sized province. The population of approximately one million is distributed so that about 55% are

located in the major metropolitan area of Winnipeg. Most of the remainder reside in small to medium-sized communities or on farms in the rural southern portion of the province. Farming has always been a major economic activity in Manitoba. While many of the farms are large, mechanized grain operations, there are also many mixed farms, livestock operations, etc.

As is the case elsewhere in Canada, traumatic spinal cord injuries in Manitoba occur most frequently to males in their early adult years. The incidence of spinal cord injury averages about thirty-two (32) new traumatic cases per year. In addition, there are approximately twenty (20) new spinal cord injuries per year due to non-traumatic causes. In total there are about 600 spinal cord injured persons residing in the province at this time. The incidence of spinal cord injury is fairly evenly distributed on the basis of population but for a variety of reasons there is a net migration to the Winnipeg area after injury. As a result, approximately 2/3 of the paraplegics within the province reside within the Winnipeg area and 1/3 in the rural areas. In the rural area itself there is evidence to indicate a migration from the farm to local communities after injury but statistics are not available on this. Despite these trends paraplegics have chosen to return to their farms and many have been successfully re-established in this endeavor. Success in this area has encouraged the Canadian Paraplegic Association to focus more attention on the paraplegic farmer in recent years.

In Manitoba there is one Spinal Cord Injuries Unit for the treatment and rehabilitation of persons in the province. This Unit - located in the Rehabilitation Hospital of the Health Sciences Centre in Winnipeg - forms the focus of a modern, comprehensive system of care to which all citizens have access through the provincial Medicare system. The Canadian Paraplegic Association provides in-hospital social services and a variety of community-based counselling and follow-up services on a life-long basis to persons who are receiving, or have received treatment in the Spinal Cord Injuries Unit. As such, C. P. A. services are coordinated with the broad range of other disciplines to form part of the Manitoba Spinal Cord Injury care program. These include the traditional in-hospital disciplines such as medicine, nursing, Occupational Therapy and Physiotherapy, as well as an excellent Rehabilitation Engineering Program with an innovative Special Devices component to which individuals in the community have access. Various community care and home support services round out the program. While based in the Winnipeg Health Sciences Centre, there is a rural "Outreach" component and a variety of efforts are made to deliver services equitably to residents throughout the Province. The Canadian Paraplegic Association assists patients to resettle in the community upon discharge from the hospital and thereafter follows them up on a regular basis in rural as well as urban areas.

VOCATIONAL REHABILITATION AND THE FARMER

Vocational rehabilitation is a major component of C. P. A.'s client services program. This begins right in the hospital when the patient and family are ready to deal with the topic. Where possible, the patient's former vocation and pattern of life is disturbed as little as is practical. Often this is not feasible nor desirable but where the paraplegic is a farmer, there is often a great deal at stake. The viability of the paraplegic as farm operator is often central not only to the individual's vocational future but also his home residence, his family life and indeed his whole role in the community within which he has grown up and planned to spend his life. There are thus very strong bonds to the vocation of farming, despite the reality that it is an arduous, physically demanding profession. If the individual is unable or unwilling to work hard at it, the business may fail. This failure can cause an effect which ripples through many areas of the family's life. Therefore, the decision to return to farming or to seek another vocation is a central one which must be made very early on in the rehabilitation process.

In our work with farmers we have found that strong family and community support are key factors in the success or failure of the farmer who works his land. It is therefore crucial that the rehabilitation planning for the paraplegic or quadriplegic farmer involve from the outset, the family of the individual and an explicit understanding of the role of community members.

We do not rely to a great extent at this early stage on the traditional vocational rehabilitation assessment tools such as interest and aptitude testing. The primary concern is a question of motivation and physical capacities. The Occupational Therapist obviously plays an important role in the latter, but the ingenuity of the farmer and the adaptability of the farm family are key ingredients in determining whether the return to the farm will be viable. We place great reliance on the family and in particular the farmer, working out their own individual solutions to the problems presented by the interplay of the individual's functional disability and the nature of the particular farm operation. We have found the demonstration effect and moral support offered by another successful disabled farmer to be a very useful support in the family's decision-making process. By putting a newly-injured farmer and his family in contact with one of our members who is successfully operating a farm, we are tapping a resource which is of the utmost importance. In fact this contact may be the single most important factor in helping the new paraplegic make the right decision and approach problems in a pragmatic, sensible way. Another way to accomplish this is to have the farmer attend at an early stage, a "disabled farmers' conference". Recent experiments with this type of experience indicate that they can

meet a real need.

ACCOMMODATING THE FARMER AND HIS FAMILY

In our experience there are three major areas where the disabled farmer and his family have needs which require attention. In the technical/ mechanical area there is no getting away from the need to modify equipment and devise solutions to technical problems. Common technological problems relate to mounting and controlling farm machinery, hitching equipment to the tractor, fueling the tractor, moving about the farmyard, negotiating barns and buildings and tending livestock within close confines. In this area we stress the importance of appropriate technology i.e. devices which are easy to operate and repair (hopefully right on the farm, or at least in close proximity). The Rehabilitation Engineering Department at the Hospital, particularly the Special Devices Program, can be useful in assisting the farmer to find solutions to the above problems. However, it is generally impractical for them to provide on-the-spot servicing of equipment and usually servicing needs are immediate as the equipment cannot be allowed to lie idle for a long time. Ways and means of overcoming this predicament must be found.

A second area in which the individual and the family find problems is that of coping emotionally with the psychological trauma of the disability. This is an individual matter which varies from person to person and family to family, but is not markedly different for farmers as a group than for other persons. C. P. A. provides counselling and advice in coping with this adjustment and provides support as needed, often for years after the injury. There have been many occasions when serious discussions about adjusting to the disability have occurred around the kitchen table during a C.P.A. counsellor's visit. We make a special effort to recognize the problems of other key family members, such as the spouse of the disabled person, in this adjustment process. The burden weighs heavily on all members of the family causing stress and tension which may lead to family breakdown if not dealt with appropriately.

The third major area to be addressed is that of task re-assignment within the farm operation. There are simply going to be some things that the paraplegic can no longer do and for which he must have assistance from other family members. We find it important to assist the farmer to identify these areas and to ensure that the family member who assumes responsibility for some of the paraplegic's former duties is recompensed so that he or she does not become over-burdened in the process. We may counsel the paraplegic for example, to assume certain home management duties otherwise part of the spouse's role, or to perhaps invest in labor-saving devices within the home, as well as in the farming side of the operation.

On an on-going basis, C. P. A. staff will follow-up the farm family in their home and provide consultation with problems that arise over time. This support and consultation will be offered not only to the farmer and his family but also to the community. It is important that the problems faced by the paraplegic farmer be dealt with in a holistic manner. Architectural accessibility to churches and community halls and acceptance by one's peers as a valuable member of the community is important in the whole process.

A PEER GROUP MODEL

As stated earlier, the ultimate success of the farmer's return to his farm will rest with the motivation and the capacity of the farmer and the family to deal with the situation. This can be encouraged and supported by C. P. A. workers but the farmer needs to believe that this is a viable option. In recent years a particularily efficient and successful support mechanism has been the Paraplegic Farmers' Conference. The first such conference was held in Winnipeg in 1981 and has formed the model for a number of similar conferences held in various parts of North American in the few years since.

Essentially, a forum is provided in which disabled farmers and their families can come together and discuss their problems and the solutions they have worked out. These conferences seem to work best when approached from an agricultural, rather than a medical perspective, as this is the approach the paraplegic farmer takes to his life. Without exception these conferences have been well-received by the farmers and their families and have led to calls for an on-going information exchange network and series of on-going conferences. We see this as a natural outgrowth of our Association's work with paraplegic farmers and feel it will provide a natural forum for the coming together of the medical, psychological, technical and economic dimensions of the disabled farmer's life.

CONCLUSION

While farming has never been considered an easy life at the best of times, the additional constraints imposed upon a paraplegic operating a farm are considerable but not prohibitive. Technological advances have made it possible for farming to be a viable option for individuals who become paraplegic. However, additional supports, interventions and adjustments are required on behalf of the individual. These run the gamit of good medical care in conjunction with a team of professional people, innovative rehabilitation engineering personnel and practices, counselling and support from agencies who work with injured persons and their families, community and intra-family support, as well as peer group interaction. The interplay of all these systems and the people who are involved within them, can help the farmer continue in his chosen occupation.

THE ECONOMICS OF DISABILITY WITH PARTICULAR REFERENCE TO REHABILITATION ENGINEERING

David C. Symington, M.B., Ch.B., F.R.C.P.(C), Queen's University at Kingston, Kingston, Ontario, Canada K7L 2V7

ABSTRACT - The major costs to society of handicap are institutional care and income support (over $10 billion in Canada annually). Rehabilitation has a significant role to play in improving the quality of life of handicapped people, while reducing social costs. To achieve these objectives rehabilitation professionals require agreed goals and a cost-effective service delivery system.

RÉSUMÉ - Les principaux coûts que représentent les personnes handicapées pour la société sont liés aux soins en établissement et au soutien du revenu (plus de 10 milliards de dollars au Canada chaque année). Bien que la réadaptation joue un rôle important dans l'amélioration de la quantité de la vie des personnes handicapées, elle a aussi un rôle à jouer dans la réduction des soûts sociaux. Pour atteindre ces objectifs, les spécialistes de la réadaptation doivent avoir des objectifs sur lesquels ils s'entendent et un programme de prestation des services qui soit efficace en fonction des coûts.

Concern over government deficits and the escalation of spending on social programmes is so commonplace in our daily news that we may by now have started to take it for granted. With the complexity of government financing and economic policies there may well be a tendency to view fiscal restraint as the government's problem, but not ours. Anyone who has been in the business of health care delivery for some time must, however, be recognizing the effects of restraint on the delivery of our services. It is clear that the very nature of our professions will be directly shaped by government restraint for the foreseeable future. It is, therefore, no longer possible for those involved in the delivery of health care services to ignore economic considerations.

While reducing costs is only secondary to the humanitarian objectives of rehabilitation, its significance in terms of the future of rehabilitation cannot be underestimated. If costs cannot be reduced, existing programmes will be cut or underfunded to the point of being irrelevant.

If we are to adequately meet the needs of handicapped people, now and in the future, we must become increasingly aware of the cost-effectiveness of our services. Are they meeting the needs of handicapped persons at the least possible cost? We must identify the gaps and the overlaps in the services we provide to determine if they are meeting all the needs of each handicapped individual. This will demand an awareness of the economic issues related to disability as well as a far greater degree of co-operation than in the past.

To understand the economic issues related to social services for the disabled we must first appreciate the scope of disability in our society. The wide range of overlapping policies related to disability reflect the existing ambiquity of the concept. Clarification of the terms disability and handicap is required, if we are to create new cost-effective solutions to improving the quality of life of these people.

The International Classification of Impairment, Disability and Handicap defines Disability as 'any restriction or lack of ability to perform an activity in a manner or within the range considered normal for a human being'. Handicap is defined as 'a disadvantage for a given individual resulting from an impairment or a disability, that limits or prevents the fulfillment of a role that is normal depending on age, sex and social and cultural factors for that individual . Handicap represents social, cultural, economic and environmental consequences of an impairment or a disability'.

In considering the economic consequences of disability, we are primarily concerned with the limitations imposed on an individual's ability to care or provide for himself or herself, the handicap that is of primary importance.

Two of the major expressions of handicapping conditions are an inability to look after one's own personal care and the inability to work and to be financially self-supporting. These two expressions often result in institutionalization and dependence upon income support respectively. Lesser degrees of handicap can impair social mobility and integration, reduce earning capacity, affect enjoyment of leisure and burden families with

extra costs and work.

The two major costs to society related to handicap are the cost of institutional care and of income support for the handicapped. The total cost of these 2 services is in the range of $10 billion per year in Canada.

To this social cost must be added the cost to society of the lost taxes and lost productivity of family members who spend time supporting disabled family members.

Despite this major social cost, the needs of the handicapped people the services are designed to provide for are still not met. The recent Parliamentary Committee on the Disabled and the Handicapped investigated the needs and desires of disabled people and showed clearly that they would prefer not to live in institutions and would prefer to work whenever this is possible.

Rehabilitation and associated community support services can reduce the need for institutional care and enhance the employability of disabled people. They can thus achieve the goals which disabled people seek, while at the same time reduce the cost to society associated with supporting the disabled. The challenge facing the rehabilitation community today is to develop a programme of rehabilitation services which will meet all the needs of all disabled people in a cost-effective manner.

The key to cost-effective rehabilitation is in allowing the handicapped to achieve their maximum level of independence. This means assisting them to be able to live in the community, and to be gainfully employed. Partial rehabilitation is not adequate in terms of the quality of life of the handicapped person involved or in terms of economics. Studies show that the greater the level of independence achieved through rehabilitation the greater the long-term cost-effectiveness. Rehabilitation which leaves certain needs unmet denies the handicapped person of a certain quality of life while leaving long-term costs which society must sustain.

Achieving the full potential of rehabilitation must become a priority for governments and service providers, if the escalating cost of social services are to be curbed. Rehabilitation services have traditionally be fragmented and inadequate, leaving many gaps in needed assistance. To achieve the full potential of rehabilitation, services must be expanded and co-ordinated. This co-ordination can only be achieved, if we estabiish clear objectives and a time-frame for achieving them.

Toward this end I propose 2 national goals:

1) A reduction in the need for institutional care by 30% over the next decade;

and

2) A reduction in the level of unemployment among disabled Canadians to the national average, over the next decade.

The achievement of these goals would mean that the cost of support services in these two areas could be reduced by 30% or approximately $3 billion annually. The money saved in income support and institutionalization could be used to expand rehabilitation and community support programmes and enhance the quality of life for handicapped people.

What does this imply for rehabilitation professionals?

Each rehabilitation specialty has great potential to influence the whole prpcess and system of service delivery for the handicapped. To accomplish this, however, each must define its role in relation to the other rehabilitation professionals and community services involved. A commitment to greater co-operation means involvement with other members of the rehabilitation team in clarifying the dimensions of particular problems and in devising innovative, cost-effective solutions.

While improving the quality of life of handicapped people, rehabilitation professionals can also contribute greatly to reducing the costs to society of institutional care and income support. The need for creative interfaces which will permit people to live more independent and productive lives is infinite. The development of more cost-effective services and technology is needed to assist more handicapped individuals to live in the community rather than in institutions. Similarly, services and technology must be available to assist the handicapped in performing useful employment, which would enable them to be economically self-sufficient.

What does a more co-ordinated system of rehabilitation mean for rehabilitation engineers? There are three major categories of handicap requiring rehabilitation services. First, there are those with chronic physchiatric illness and foremost among these is the large group of elderly people suffering from dysfunctional brain syndrome or senile dementia. Secondly, there are those with mental retardation and thirdly, those with physical disability.

Rehabilitation engineering has put insufficient emphasis and effort into the rehabilitation of those with psychiatric illness and mental retardation. These disabilities are equal in magnitude to the problem of physical disability, yet, much less effort has been applied to engineering solutions, which would improve the quality of life of persons with these disabilities. The role of engineers in the overall rehabilitation of these people should be defined and expanded in the future.

To further expand the role of engineers in the rehabilitation process, emphasis will be needed on developing solutions which can be standardized, so as to be available in the most cost-effective way possible. Emphasis in the past has tended to be on customized solutions.

To focus the efforts of rehabilitation engineering, the speciality should consider further its contribution to the two goals reducing the need for institutional care beds and reducing the level of unemployment among handicapped.

FROM CAVEMAN TO SPACEMAN: SOME REFLECTIONS ON THE SOCIAL AND VOCATIONAL SITUATIONS OF PERSONS WITH DISABILITIES

Wilfrid B. Race
Communications Division, Workers' Compensation Board of Ontario
Toronto, Canada

ABSTRACT - This presentation reviews some of the historical considerations underlying the current situation of persons with disabilities, and suggests some of the ways that space-age technology can affect their lives and lifestyles.

RÉSUMÉ - Cette communication passe en revue certaines des considérations historiques qui sont à la base de la situation actuelle des personnes handicapées et propose certaines voies par lesquelles la technologie de l'ère spatiale peut influer sur leurs vies et leurs modes de vie.

The organization for which I work, the Workers' Compensation Board of Ontario, has been in the vocational rehabilitation business since 1924. This means that we are now celebrating our 60th anniversary in this important field. VocRehab, as we commonly call it, has come a long way over the years, to the point where it is a multimillion dollar operation, involving a wide range of professional disciplines.

Traditionally, vocational rehabilitation programs, especially those established by governments or depending upon government financing, have taken their main justification from the argument that they ultimately lead to public economy by transforming what would otherwise be recipients of welfare into tax-paying citizens. To some degree, this argument still has some fashion, but I do not think we are quite so cold-hearted about it as we used to be.

There is no doubt that the provision of adequate rehabilitation services results in significant socio-economic benefits to society as a whole, and this is highly desirable; but it is also desirable to take into account the wide variety of needs of the individuals concerned. Human beings, by their very definition, are much more than mere taxpayers. This is why today we put as much emphasis on the social and psychological aspects of rehabilitation as we do on the purely vocational. We believe it is the person's right.

I should like to mention now what I think are some of the implications of all of this for people such as yourselves who are playing an immediate role in the technological revolution that is having such a profound affect upon the lives of us all.

Those of us who are not engineers, or who are not engaged in other modern scientific endeavours, are constantly bewildered by the rate at which new "miracle" machines are being developed. Space-age technology seems to be progressing at a speed rivaling that of the creation of the universe after the first "big bang". Knowledge is growing almost faster than our ability to store it, and we are left wondering whether we have the mental and physical capacity to cope with it all. I can recall reading a few years ago that when the steam engine was first invented, the medical profession was concerned that the human body would not be able to withstand the shock of being hurtled along at the horrendous speeds that this new machine would give to human locomotion!

But one of the things that the twentieth century has taught us is that man is more adaptable than we ever imagined him to be, that he is capable of living and surviving in a variety of worlds (I am now speaking in sociological terms), and that he has an inner mechanism that allows him to make enormous mental and emotional adjustments over a relatively short span of time.

A corollary of the proposition that I have just stated is that humankind's expectations can be streached as much as its imagination. What is innovative today, is taken for granted tomorrow, and that which is a luxury today, is tomorrow's necessity. And so it goes on. Yesterday's wheel is today's microchip, and who knows what it will be ten years down the road? What is crucial here is that it took millenia to get from the wheel to the microchip, whereas it will probably take little more than a decade to make the next comparable leap. I exagerate, of course, but probably not excessively.

What affect is all of this having upon the generation gap? I look at what my children are studying in high school, and much of it isn't even vaguely familiar to me. While I studied algebra and geometry, they study functions, whatever that is! To them, 'geopolitics' is an outdated term; I studied it at university! Just about everything I know is passee. My youngest daughter, who is in first year highschool, is studying the Korean war in history.

To the younger generation, the only people who seem to have any knowledge that is 'current' or 'worthwhile' are the technologists without whom we would not have ataris and home computers. They are the "in" people. They are the ones who are building our electronic utopia. And even though I may be looking at it from a different perspective, I have to agree: they are building what could become a real utopia for many people whose lives have been severely restricted to date, and who may have had little hope of ever participating in this world on anything like an equal basis with their fellows. And I say all the more power to them, and let's get on with the job!

Within the disabled community today, independent living is seen as the key to emancipation. This concept does not merely refer to a system of accommodation wherein an individual has his or her private apartment or other dwelling unit. Independent living embraces a philosophy of life which recognizes the individual's right to complete self determination, including full control over the direction his/her life is to take, and freedom of choice as to the nature of lifestyle. It removes all the artificial restraints which traditionally have been imposed upon disabled persons by members of the helping professions and by society as a whole. It returns the decision making responsibility to the individual concerned, and this includes the responsibility to make mistakes.

For many disabled persons, complete physical self sufficiency will never be a realistic goal, but that does not mean that the goal of independent living cannot be attained. It is fully attainable by individuals whose medical conditions are reasonably stable (i.e. persons who do not require regular medical attention), and that comprises the vast majority of people with disabilities.

Even people who cannot be totally physically independent are now offered the promise of being able to do much more for themselves as a result of the various electronic devices that are drastically changing the lifestyles not only of the physically disabled, but of the able-bodied as well, and to this extent they are bridging the gaps that previously existed between the two groups. This, in turn, has an immensely beneficial psychological impact upon the disabled which contributes to the attainment of an even higher level of rehabilitation.

At the Workers' Compensation Board of Ontario, we consider independent living to be an integral part of our vocational rehabilitation efforts. We are as concerned about the injured worker's access to, and enjoyment of, his or her home as we are about finding a suitable job placement because we know that a secure and supportive home and social environment are essential to good performance on the job.

Independent living also means being able to be mobile within one's community and beyond, and being able to take part in community activities. All of this illustrates quite clearly, I think, that the concept of independent living requires a complete and well integrated system of services and facilities that are readily accessible to those with disabilities.

As a social phenomenon, physical disability has existed as long as mankind has occupied this planet. And yet it has only been in very recent times that society has felt that it had any responsibility for dealing with the problems confronted by the disabled, or shown any willingness to devote precious resources to their solution. Rehabilitation engineering is a very new profession, and this is only its second international conference. Has it come on the scene so recently because the technology to produce assistive devices for the disabled has become available just in the last couple of decades? I don't think so. I suggest that it was mainly the result of a significant change in the way society began to look at its disabled citizens, seeing them as assets and not liabilities. And that is what occured only a couple of decades ago!

Glasses are probably one of the earliest forms of technical aids, and they have been around so long, and gained such widespread acceptance, because they were, and are, needed by so many people. I would venture to say that our modern civilization could not have developed if we had had to depend upon a majority of our citizens who could not see particularly well. If as few people required eyeglasses as require myoelectric arms, chances are that optometry would not be the state of the art that it is today!

It is not at all surprising that the environment that man originally created for himself was designed and constructed for the able-bodied. Man is an upright creature (and I hasten to add that I mean that in the physical sense, not the moral one). He walks about on his hind extremities, leaving his arms and hands free to perform a wide variety of functions. Survival was early man's chief preoccupation, and physical fitness was a major prerequisite to that all absorbing process. To protect himself from predators and/or inclement weather conditions, he devised housing arrangements which were either off the ground (either on stilts or carved into cliffs), or elevated on platforms made accessible by steps. Steps and ladders were marvellous technical innovations for homo erectus who wished to operate on different levels.

Special consideration for people with physical disabilities only became practical after many millenia, when a tribe or clan no longer required the strenuous physical input of every member in order to survive. But even in these more sophisticated cultures, one virtually had to be a member of the very restricted liesure class, if one

were to lead any kind of a tolerable life with anything but a relatively minor disability. Even the wheel, that brilliant scientific advancement upon which entire civilizations were based, was used until quite recent times almost exclusively as a vocational tool or as an aid to waging war. It has always amazed me that the litter, or sedan chair, remained a popular means of conveyance in some cultures for generations after wheeled vehicles were invented.

No event in history had as great an impact upon the way men and women earn their livings, or caused as much social and technological upheaval, as the Industrial Revolution. It is still one of the favourite topics of historians and sociologists, because it totally changed the social order. In its earlier stages, it was characterized by horrendous working conditions and great devaluations of human dignity. It brought in its wake numerous new threats to the health and well-being of workers, and even today we are far from solving all of the problems found in the field of occupational health and safety. The workplace continues to be a major source of disabling conditions. Some occupations involve much higher risks than others, of course, but none of us is entirely without risk. Each year the Ontario Workers' Compensation Board deals with about 350,000 new injury claims, and this rate of industrial injury is not out of line with other jurisdictions in North America.

But if the Industrial Revolution produced conditions that were a threat to the life and limb of the ordinary citizen, it was also as a result of those very conditions that a cadre of reformers emerged who were determined to alleviate at least the worst of the industrial abuses. Their great contribution was that they were basic to creating a new social consciousness that demanded government intervention to attain a safer and more secure environment for people to work and live in. These measures were very elementary and inadequate in the early stages, but they provided the foundations upon which our entire complex system of social services rests today.

For people with disabilities, the tragedy was that they were lumped into that amorphous grouping of people who were considered incapable of looking after themselves. As a result, the kinds of provisions made for them were, for scores of years, limited to custodial care and/or minimal income support. Many people were confined in institutions in which they just languished, and those who were able to remain at home with families were not allowed to aspire to normal life expectations. They were anomalies in a world that was built by and for the physically able.

This bent of mind persisted for centuries, and, amazingly, lasted virtually intact until well into the 20th century. It was only with the rise of powerful advocacy groups that public opinion gradually began to see disabled people as potential participants in, and contributors to, their communities. Even designers of early technical aids were more concerned about the ease and convenience of the custodians than they were about those in the custodians' care! Early wheelchairs, for example, were not intended to enhance the independence and mobility of disabled persons, but rather to make it easier for the staff to move them from place to place within the institution.

You will see, then, that those of you who are engaged in this new field of rehabilitation engineering are pioneers in a very real sense. You who are involved in the development, promotion, and application of sophisticated technical aids intended to overcome, or compensate for, various kinds of disabilities, are a part of a fairly new breed of people who have been able to escape the confinement of centuries-old stereotypes to see human beings for what they really are.

I should like to say a few words now about the way disabled people may react to the introduction of technical aids into their lives. It is not always perceived as an unmixed blessing. A very simple simple illustration of this is the person with neuro-muscular dysfunction whose independent mobility is gradually declining. The time will eventually come when he/she will have to face the prospect of having to use a wheelchair. It is not an easy thing to face. It is fraught with many concerns. The individual may worry about how his/her friends will react to the new situation. Will they feel awkward and tend to appear on the scene less frequently? Will he/she become isolated? Will the children be embarrassed? Will he/she deteriorate more quickly by "caving in" to the disability? These are all quite normal concerns that must be countered by positive supports on the part of both health professionals and other persons in the individual's life.

Most of us treat our bodies with the respect they deserve. We want to keep them in good working order for as long as we can because of the many things they allow us to do and the many pleasures they give us. Health awareness and physical fitness are taught to us at an early age as good habits of life. It is extremely traumatic, then, when we are faced with a sudden and serious disability from which we may never fully recover. The shock, disbelief, and even anger are phenomena well known to health care workers and rehabilitation personnel.

One of the unfortunate psychological aspects involved in the sustaining of a serious injury is that it places the individual in a position of dependency. He surrenders control of his own life, and is placed in the care of others. Vital decisions are often made on his behalf,

and the daily routine of his life is determined by others. If the injury is very serious, this may continue for some time, and when the patient eventually reaches the stage where he can start reclaiming some control over his own life, his capacity to do so may have diminished. Decision making essentially involves risk taking, and this can be a difficult departure from the sheltered protection to which the patient has become accustomed. A dependency syndrome may have set in. This is why it is so crucial to begin the rehabilitation process at the earliest possible time, and to involve the patient intimately in every stage of it. He should be a major participant in every decision taken.

We normally associate risk taking with playing poker, with stock market ventures, or with crossing the street against a 'do not walk' sign. Risk taking in rehabilitation can be defined as making choices after juxtaposing potential benefits with potential losses (both real and imagined), and it is a necessary process if the dependent person is to move toward independence. He gambles dependence and security against uncertainty, possible pain, or even further damage to his body. But the payoff is independence, dignity, and career development, and this is usually sufficient to motivate risk taking behaviour.

Technology enters this matrix in a number of ways. A piece of technical equipment may actually appear threatening to some people, and its imagined potential for harm can reduce risk taking behaviour in some cases. When we consider how reluctant some people are even to wear glasses, this should come as no surprise. For most individuals, though, the willingness to take risks is greatly increased by the introduction of personal technical aids because they can serve as suitable replacements for the dependence that they are being asked to give up. They can actually enjoy 'showing off' their new toys! Moreover, any fear of harm that might come from the device can often be significantly reduced by the enthusiasm, and even excitement, shown by therapists and rehabilitation counsellors about the benefits to accrue from using the appliance. Their confidence can be transferred to the recipient of the device in a very reassuring way. Thus it becomes apparent that the psychological environment within which a technical aid is presented to the recipient can have a marked affect upon his acceptance of it and his ability to gain maximum benefit from its use. Indeed, the aid can even be seen as tangible proof of real benefits to be gained. This, of course, is the desired goal.

Perhaps the most dynamic aspect of the development of sophisticated electronic aids is not merely the vocational opportunities that they afford, but rather the equalizing affect that they have by helping to diminish the social gulf that exists between disabled and non-disabled people. Computers and other electronic equipment are changing the employment patterns of large numbers of workers, and some sociologists forsee the day when the home will also become the office. Having all employees 'on the premisses' will no longer be such a firm requirement. Automation is already removing the need for manoeuverability in many operations, and several types of activity can be controlled from a single location. Electronic information systems, such as telidon, can put information gathering at one's fingertips. There can be no doubt that the pushbutton age is going to greatly simplify the vocational and the social problems of the severely disabled.

Computers can also be of considerable value in helping people with disabilities to find suitable employment. In the Employment Services division of the Workers' Compensation Board, we put known job vacancies throughout Ontario into a computer, which also contains the profiles of rehabilitated injured workers. In this way, we can readily match job-ready people with available employment opportunities. The system is working extremely well, and has greatly improved the efficiency and effectiveness of our placement services.

Well, Mr. Chairman, we have surveyed a lot of territory in a short period of time. We have seen that this conference, ICRE II, is in many ways the culmination of many centuries of searching for the most enlightened approach to the occurence of disability within society. The advances in rehabilitation engineering in the past few years have been staggering, at least to a layman such as myself, but their potential for good is unprecedented in humankind's history. It is an exciting field, and one towards which many eyes will be turned as we dare to hope for the solutions to so many problems of disability which heretofore appeared insoluable.

R.J. McElroy
Disabled Persons Employment Directorate
Canada Employment and Immigration Commission
Hull, Canada

TEXT OF PRESENTATION NOT AVAILABLE

TEXTE DE LA PRÉSENTATION NON DISPONIBLE

ABILITY COMMUNICATIONS NETWORK

George J. Rochon
Ability Communications Network, Winnipeg, Manitoba

ABSTRACT - This paper outlines the philosophy of the Ability Communications Network recently established in Winnipeg. The objective is to utilize as effectively as possible the enormous potential of microcomputers and computer networks to benefit disabled persons.

RÉSUMÉ - Cette communication décrit la philosophie de l'Ability Communications Network récemment mis sur pied à Winnipeg. Son but est d'exploiter de plus efficacement possible les énormes possibilités des micro-ordinateurs et des réseaux informatiques au profit des personnes handicapées.

"In some industries work modules that can be adapted to any location can be developed and made available to the disabled at home or in sheltered work environments. This appears possible in the computer and electronics industries where communications between plant and worker can be maintained through electronics and telephone hookup."

Labour Market Development in the 1980's
Employment and Immigration Canada

With the spectre of 85% unemployment hanging over the head of the disabled, new concepts had to be introduced to ensure that this minority group was brought into the workplace.

Advances in technology now makes it possible for those who cannot go out into the world of buisness, without undue hardship, to have the world brought to them.

These advances, as applied to the disabled, have led us to coin a new word "TECHNOBILITY".High-Tech will be the great equalizer in the world of tomorrow.

The purpose of this paper is to highlight the major benefits of the broad based, multi-function, multi-user Ability Communications Network as advocated in part in Labour Market Development in the 1980's, and to indicate specific areas where this network would apply.

There is little doubt that a revolution has occured in computer technology for all organizations during the post war period. A major element of that revolution has been the development of computer networking. This new technology, which is still in a state of constant improvement, has made possible the efficient growth of large and complex networks.We believe that this technology will have a profound effect on the disabled. However, computer technology must be carefully applied. Computers alone will not satisfy all the needs of the disabled. The computer simply provides an organization with the capacity to process and distribute data efficiently. It does not necessarily contribute to the effective use of the information.

This is an important distinction.By efficiency,we mean the cost benefit ratio of supplying education and employment to the disabled. It typically costs less for the disabled to work from their home than to have them attend various colleges and workplaces where special devices, attendants and transportation are required. By effectiveness, we are concerned with the whole new range of educational and employment potential that is opened up by the development of computer systems. Computerized network systems should be developed to satisfy the maximum number of purposes and functions as applied to the disabled.

The computerized network system should be designed to do more than replicate the existing programs for the disabled. The essential power of the computer is its multi-use function.The more types of software and data made available, the more types of functions can be accomplished. These would include education, self-employment,employment with outside agencies and monitoring services. The social aspects of interfacing with other disabled persons must also be taken into consideration.

It is interesting to note that systems of this type are in use by the non-handicapped, yet no steps have been taken to bring this technology to the people who would benefit the most from it. Although the technology has been adapted for the disabled by such agencies as NRC, delivery of this technology has been slow due to the fact that there is no single co-ordinating agency to ensure quick and easy funding.

We decided that the principal effect of this system would be to reduce unemployment in the target group, which contains a disproportionate number of workers who need special assistance. Assistance would have to be provided to find productive employment and to achieve advancement in the job hierarchy. It would help to eliminate systemic discrimination and economic and social patterns which continue to limit the employment opportunities of the disabled.

At the entry or re-entry level, opportunities would be improved through better pre and post-employment training and accessability to the workplace via the network. At the innovative level, training and employment will be made possible, for high level Quads and others with limited hand function, by an innovative

new idea in the delivery of unmodified commercially available software. Another major effect of the system will be to establish a national communications network for the disabled and the various groups and organizations which represent them. We believe, however, that the principal effect will be the tapping of a vastly underutilized resource in this country the DISABLED.

The project involved intensive study of the problems associated with existing systems. It was found that the technology was readily available to create the network including the necessary software. Technical aids to enable the severely disabled to operate the system were available but were designed to interface with foreign made hardware. It was also found that no system existed to deliver commercially available, unmodified software to high level quads. This led to the development of interfacing equipment for Canadian made hardware and a software delivery system.

However, the problems concerning employment of the disabled, which this system is designed to address were rather more complicated. These problems are well documented and can be found in a number of studies.A broad range of alternative solutions to the problems of employment among the disabled were reviewed. Although some programs have shown some limited success, tokenism appeared to be the order of the day as the unemployment figure of 85% graphically points out. Rhetoric abounds while action does not. This initiative seeks to remedy that situation.

The network must respect the need for different requirements among the disabled and their parent organizations. This system falls short of providing a "packaged solution". The system as developed is designed as an illustration of what can be accomplished if the various government agencies and consumer organizations cooperate.Many variations on this theme are both possible and advisable. The problems of unemployment among the disabled must be addressed now in a positive and innovative form.

We have developed a system that is comprehensive. It is a major program for the disabled. It has far reaching implications and recognizes the way the disabled can now become an integral part of society through the use of science and technology. The use of this technology must be controlled by the disabled for the disabled. To often when outside agencies have been funded to assist the disabled, the trickle down phenomenon occurs. The disabled have received just a trickle.

Initiatives towards creating various types of networks to interconnect organizations representing the disabled have, on the whole, met with disastrous results due to poor planning or lack of proper funding. The proliferation of consumer and service agencies representing the disabled, on a national scale, led to many and varied plans for networking within the respective agencies. It became apparent that a centralized agency dealing strictly with high-tech and its implications for the disabled was badly needed to avoid fragmenting the system.

To meet this need CCG Inc was founded.With the help of various agencies, government, private and public institutions, the ACN was taken from the conceptional stage to the pilot project in just 3 months. The main priority was to create one national network with standardized equipment and procedures, to serve all the disabled and the agencies and organizations representing them. It would also have to meet the recommendations of Obstacles. The second priority was not only to provide a comprehensive information and resource network, but one that would provide referral, education and workstation facilities for the severely mobility impaired. The third was to Canadianize the system.

The problems of building a system that satisfies the needs of all participants presented us with an interesting challenge. It was therefore decided to create a completely modular system. To accomplish this, hardware had to be selected that was readily interchangeable within the system and compatible with the adaptive devices for the disabled. This allowed users to build a system according to their own particular needs. Due to the fact that the system is modular it will provide protection against obsolecence. The short lifetime of developments in technologies makes this problem very acute.

A final consideration was the requirement for national information gathering and transfer. To this end iNet was chosen as the data communications system.

A pilot project was launched funded by a grant from CEIC. With assistance from Computerland, Telecom Canada, MTS, COPOH, CRCD, CPA, Nelmn Data Corp and HSC Rehabilitation Engineering a test network was put in place.

The purpose of this network was to test the viability of the hardware and software in a network situation. Adaptability to the disabled was also to be tested. To this end terminals for educational, workstation, service agencies, rehab engineering & consultants were put in place. iNet has been connected and tests were carried out using computer terminals and a "Displayphone" supplied by MTS. Tests so far appear to indicate that all hoped for results will be achieved if not surpassed.

The concepts and methods of implementation presented here are not, and can never be, the definitive answers to all problems facing the disabled in this era of ever changing technologies. They will, however, allow the disabled to leap directly from a "first wave" to a "third wave" society, to use Alvin Toffler's terminology.

Although in its infancy, the use of microcomputers in rehabilitation is showing some very useful results. We have only just begun to tap the potential of these new tools. Through innovation and cooperation from all levels of government & industry the full potential can and will be reached.

TECHNOLOGY: A TOOL TO FACILITATE EMPLOYMENT OF DISABLED INDIVIDUALS

Jack R. Clarcq, Ph.D
National Technical Institute for the Deaf
Rochester, U.S.A.

ABSTRACT - In today's technological world, disabled people need to develop competencies for entry into, and accommodation in, the work place. This paper presents a process for career development of disabled individuals and provides examples of how technology is used to influence their career development.

RÉSUMÉ - Dans le monde technologique d'aujourd'hui, les personnes handicapées doivent acquérir des compétences pour pénétrer dans le milieu de travail et s'y installer. L'auteur décrit une méthode de développement de carrière pour les handicapés et fournit des exemples de l'utilisation de la technologie pour concrétiser leurs projets de carrière.

Acquisition of technical skills is a prerequisite to employment success among disabled individuals. However, skill acquisition is only one factor to consider by those involved in the education and job placement for the disabled. Other factors fall within the broad context of career development, and include career selection, career preparation, career entry, and long-term career accommodation. Since we are living in a rapidly changing technological world, the role that technology plays in career development is an important consideration.

Career Development -- A Process

Career development is a life-long process, having as its primary objective that of preparing individuals for "earning a living" and "living a life." Individuals must have the necessary competencies to secure and maintain meaningful employment and to be prepared for personal, social, and civic involvement.

Career development of a disabled individual should be initiated early in the person's life. Career selection involves relating education to the world of work and providing of opportunities for individuals to assess their values and interests relative to career options and then to select an option consistent with their values, interests, motivations, etc. In career preparation, the individual is provided with the education that will give them skills necessary to enter a career. Career selection involves selectively matching an individual to a job. Career development, however, does not end at job entry. Disabled individuals must develop skills that enable them to respond in a positive fashion to change.

Application of Technology

We are living in an era of ever advancing technology that is creating tremendous change in all human institutions. This change is having a decided impact on our lives. While we cannot be sure of the specific impact on the individual, those involved in the education of disabled individuals must design programs to prepare individuals to function in an ever changing world.

Technology can play a role in preparing disabled individuals to select a career, to develop skills necessary to enter a career, and to function in the work place. Following are examples of how technology is used at the National Technical Institute for the Deaf (NTID) at Rochester Institute of Technology (RIT) to assist hearing-impaired individuals to live in a technological world. The examples describe how technology is used to assist students and graduates (a) develop career decision-making skills, (b) assess expressive and receptive communication skills, (c) develop specific technical skills, and (d) function in the work place.

Career Decision Making

Technology can assist disabled individuals in developing career decision-making skills. The System of Interactive Guidance and Information (SIGI), is used to teach students how to make rational career decisions. This microcomputer system assists in blending a person's values with career information. Students clarify and prioritize their work values by matching values to career options. Comparative information is provided related to the advantages and disadvantages of different occupations along with information about the type of education and special skills required of an occupation. Finally, SIGI assists students in deciding the personal desirability of selected occupations.

Communication Assessment

The Master Hearing Aid (MHA) is used in the communication assessment process. The MHA simulates characteristics of particular hearing aids as they relate to an individual's residual

hearing and provides an audiologist with information that can be used to select an appropriate hearing aid that will maximize the use of an individual's residual hearing. It is a future expectation that a simulated signal chip from the MHA will be able to be implanted into the individual's hearing aid.

A second application of technology relates to communication assessment and instruction. NTID's communication skills data bank stores information on demographic characteristics of students, their communication skills, and the communication courses that they have taken at NTID. Information on students is available via computer terminal and hard copy and provides communication counselors with an understanding of the individual's level of functioning, background, and previous communication training. This data-based management system allows for the scheduling of instruction according to an individual's communication needs. Without such a system, it would not be feasible to select courses to meet the individual communication needs of a heterogeneous group of students.

Skill Development

Technology is used to assist students in the development of communication and technical skill competencies and to develop instructional materials.

A classroom has been designed where students are provided experiences in telephone communication and the use of telecommunication aids. Multiple training options are available to the individual student, depending on the person's level of communication skills. Individuals are advised to enter either the telephone or the telecommunications course depending on their expressive and receptive communication skills.

A speech spectrograph assists in improving pronunciation by providing the student with drill and practice. The spectrograph displays speech visually and matches the speech produced with the desired speech. A project, Dynamic Audiovisual Interactive Device (DAVID), provides students with speechreading drill and practice. This system combines the Computer-assisted instruction (CAI) capability of providing drill and practice skills requiring constant repetition with instructional television's capabilities of offering stimuli material in color, motion, and sound. Students work in private and are not threatened by making mistakes. Material used is taken from technical areas, thus reinforcing vocabulary used in technical classrooms.

A self-instructional learning laboratory combines various technologies, by providing self-instruction in sign language, speechreading, and writing, allowing students to work at their own pace and reinforce classroom concepts.

"Real Time Graphic Display" is a new system of video captioning that lets students read their instructor's words virtually the moment they are spoken. The system uses a stenographer, a modified court stenographic machine, and a computer to transliterate speech into printed English words on a television screen.

Microcomputers are used to develop technical competencies necessary for job entry and mobility. Microcomputers provide instruction in a variety of technical areas and provide students with opportunities to learn basic technical principles and operations related to their major, using technology that they will find on the job.

Advanced technology is used in learning laboratories to develop technical skills necessary for job entry and mobility. This technology provides opportunities for hearing-impaired students to become acquainted with the technology that they will find in a world of work.

Technology can also be used to create instructional materials for use by learners. Television is a major source of information to the hearing-impaired. However, because the audio portion is generally inaccessible to the hearing-impaired person, only a portion of the message is received. Adapting television programs, through the captioning process, provides the hearing-impaired individual with a significant portion of the message conveyed. Research conducted in the United States has demonstrated that, in an educational setting, adding captions to a video presentation facilitates the transmission of cognitive information and knowledge acquisition.

In many instances, simple and inexpensive work environment modifications can be made to facilitate accommodation of the hearing-impaired worker. For example, for approximately $700, a telephone installer has been issued a pocket TDD to communicate with the home office when in the field and a lighted probe was made on test equipment to replace the audio signal. For $25, a red safety light, which blinks when a customer is at the counter, allows a hearing-impaired darkroom operator to function in a photography laboratory. A power plant engineer is warned of an equipment malfunction via a strobe light which is frequency sensitive and a safety railing was installed to keep the individual from backing in a traffic lane. These modifications were made for approximately $250. There are many additional examples, but the point is that with a small investment, deaf workers can function in the work place.

Reverse History

The NTID experience has demonstrated that the history of the hearing-impaired person in the world of work can be reversed. As of 1983, approximately 95 percent of deaf RIT graduates who have successfully completed their training program and who have chosen to enter the labor market,

have found jobs. Approximately 94 percent have found jobs commensurate with their level of training. Graduates have found jobs across the United States in business, industry, education, and government. The graduates are working in a variety of positions formerly not available to the hearing-impaired. Hearing-impaired people now are successfully functioning with their hearing peers as engineers, lawyers, medical technicians, photographic technicians, accountants, artists, and in many other highly technical jobs. The course of history can and is being reversed.

TECHNOLOGY ENHANCES EMPLOYMENT OPPORTUNITIES FOR THE DISABLED

Valerie Brew-Parrish
Southern Illinois University - Carbondale, Illinois 62901

ABSTRACT - The paper discusses some of the employment difficulties encountered by persons with disabilities and highlights the technological breakthroughs of today and the future which will positively affect the lives of the disabled population.

RÉSUMÉ - Cette communication traite de certaines des difficultés éprouvées par les personnes handicapées dans le domaine du travail et met en relief les percées technologiques d'aujourd'hui et de demain qui ne manqueront pas d'améliorer la vie des personnes handicapées.

During the decade of the 1960's, a popular television series began each weekly episode with the maxim.. "Space--the final frontier." In a short time span of twenty years, human beings have successfully explored the facets of the universe, landed men on the craters of the moon, and have accomplished feats that were once the creative fantasies of Jules Verne. Humankind is standing on the threshhold of yet another technological revolution. This revolution is having a significant positive impact on the lives of those individuals with disabilities. To physically disabled individuals the 1980's signal an era that might be described as "Technology and computer chips -- the frontier to employment."

The purpose of this paper is to examine some of the adaptive equipment that can be used by persons with disabilities to facilitate employment. It is crucial to be aware however, that although technology can assist individuals with disabilities to live and function more independently, many factors inherently affect the employment process. Individuals with disabilities are confronted with architectural barriers, transportation obstacles, and most harmful of all, attitudinal barriers. As a person with a life long disability, I wear many hats. I am first and foremost a consumer, dedicated to improving the lives of individuals with disabilities. I am a professional career woman with a masters degree in Higher Education and employed as a placement specialist for the handicapped students at Southern Illinois University. I am a member of the RESNA Consumer Involvement Committee and lastly and most rewarding I am a wife and mother. In my position as a placement specialist, I have on numerous occasions acted as an intermediary between the person with a disability and a prospective employer who may never have interacted with a physically impaired individual before. I have shared the pain, humiliation, and frustration that was felt by graduates with disabling conditions who were rejected for employment. Likewise, I have rejoiced in a graduates' triumph upon securing professional work.

Undeniably, sophisticated technological advances has been the catalyst responsible for larger numbers of physically impaired persons entering the work force. Computer chips have made such devices as the talking clock and talking calculator commonplace. There are an estimated fifty-three million Americans who are disabled and this number steadily increases with improved medical care. Why then, has it taken society so long to acknowledge the contributions that people with disabilities can offer? Perhaps the answer can be found by remembering the not-too-distant past. Curb cuts and ramps were just about nonexistent. Persons with disabilities were totally isolated from the public. The norm varied from total confinement to the home to segregated residential schools or day schools for the handicapped. The media consistently portrayed physically impaired individuals in a demeaning way to evoke pity and a sense of helplessness. That's quite a legacy for the disabled population to live down. Conditions dramatically improved after the Rehabilitation Act of 1973 was implemented. This piece of legislation provided individuals with disabilities basic civil rights. Consequently, the barriers began to tumble somewhat. The independent living movement spurred on by Gini and Joe Laurie, editors of the Rehabilitation Gazette, and consumer groups world wide, began to catch on. Ramps began to appear and for the first time in America's history physically disabled people were able to get to places that before had been inaccessible. Consumers began to band together to become a political force in order to enact legislation that would benefit those with disabilities. Employers were mandated by the Rehabilitation Act to initiate procedures to hire the disabled. Despite legislative mandates calling for Affirmative Action to hire individuals with disabilities, not much progress has been made in this regard. Disturbingly, the Harvard Business Review has estimated that 91 percent of the 300 companies surveyed by the Department of

Labor are not in compliance with the Rehabilitation Act of 1973.[1] Other research indicates that employers are more willing to employ individuals with lesser disabilities. A survey was conducted by the Journal of Contemporary Business to determine what types of disabilities the Fortune 500 companies were most likely to hire. Approximately 43 companies responded to the survey. The results showed that employers displayed a willingness to employ disabled persons with lesser disabilities. As the severity increased, the employers' willingness to hire decreased substantially. The results also indicated that in actuality less than thirty percent of the companies had a proportion of handicapped individuals in their work force.[2]

The panacea of this dilemma may be inherent in the technology that is enabling disabled persons to live more independent lives. Paradoxically, the disabling condition may indeed be severe but the adaptive equipment can somewhat minimize the extent of the disability. To illustrate this point, consider the employer who laments the fact that the company would be willing to employ a blind person but cannot do so because the position would entail extensive reading. Today, that is not a plausible reason not to hire the blind person. Computer chips have greatly improved the lives of the disabled. The Kurzweil Reading Machine is a device that can be used by the totally blind person to read printed materials. This machine utilizes a synthesized voice that verbally reads printed words. Similarly, the Optacon, manufactured by Telesensory Inc., is another reading device for the blind. The Optacon is a portable machine that transmits printed materials into electrical impulses that can be felt by the blind person's fingers.

Partially sighted individuals have a wide assortment of low vision aids that can be used in daily living situations and on the job. The Visual Tek and Apollo greatly enlarges print on a simulated television screen and can interface with a computer terminal. The Versa Brailer is a cassette like machine that stores and plays back braille notes. These technological advancements have enhanced employment prospects for the visually impaired.

Today, blind individuals can be found in virtually every occupation. Nevertheless, it would be erroneous to assume that all blind persons are the proud owners of Optacons, Visual Teks, or other similar equipment. In fact, because of the astronomical cost of these devices, relatively few blind individuals are able to derive any beneficial use from these aids. Amazingly, by the time these devices are affordable to those individuals who could use them, they may be obsolete. In 1965, work began on the construction of an artificial eye at the University of Utah. A man who had been blinded in a hunting accident had sixty-four miniature electrodes placed into his brain. "Hooked to a TV camera, the panel stimulates his visual centers, producing tiny dots of light known as phosphenes. In the laboratory, the device lets him "see" the difference between large horizontal and vertical lines...."[3] EMV Associates, Inc., a Maryland research firm, is attempting to perfect an electrode panel that will have the capability to grow into the grain and the cells will reach into the visual cortex to provide sight. The vision will be comparable to the old black and white television sets.[4]

One of the most overwhelming obstacles to employment for the physically impaired person is caused by the preconceived ideas and attitudes that employers generally believe to be true regarding the hiring of someone with a disabling condition. Misconstrued notions about hiring persons with disabilities have persisted for decades despite the numerous studies that have conclusively pointed out that disabled employees are an untapped resource with great potential. Consequently, persons with disabling conditions still find it extremely difficult to obtain suitable employment. Employers have often perceived the disabled person as someone who will be sickly and therefore not a reliable employee. Back in the early 1970's the E.I. duPont de Nemours and Company conducted an extensive study to determine whether disabled persons make good employees. The duPont Company is America's sixteenth largest employer with approximately 111,000 employees nationwide. This study examined the job performance, safety records, and attendance of 1,452 duPont employees who had physical conditions that may have prevented them from doing what the non-impaired workers were required to do. The study helped to clarify some of the typical misconceptions employers associate with hiring someone with a disability. Some of these myths are as follows. Insurance rates will skyrocket, job modifications will be exhorbitant, special privileges will have to be granted, the disabled employee will not be accepted by the other employees, and safety records would be jeopardized. The duPont study showed that insurance rates do not increase when a disabled person is employed, job modifications that are needed are minimal and in most instances unnecessary. This study also indicated that 79 percent of the handicapped rated average or better, 91 percent rated average or better in terms of job performance, 93 percent rated average or better in relation to job stability, and it also pointed out that workers with disabilities do not want special privileges.

Another major obstacle to employment encountered by the disabled person is transportation. Consumer groups throughout the United States advocated for years for accessible public transportation. Attempts have been made to provide some means of transportation for the disabled in some locales but by and large accessible transportation is nonexistent in most areas. Consequently, many disabled individuals have learned to drive with sophisticated adaptations. These modifications can be exhorbitant causing the disabled person to go into debt in order to get back and forth to work and to maintain employment. The car that I drive

for instance, had to be equipped with foot-controls for steering. The steering wheel is on the floor and is turned by using the left foot. The brake and accelerator are done with the right foot. The cost of these controls was approximately $3500. The only place that does the installation of these controls is in Fresno, California.[5] Therefore, when I need to buy a car, I must pay someone to drive the new car out to Fresno to have the car modified. I must travel to California because the controls are uniquely designed for each person. Because so few people need foot-controls for driving there is no real demand for them. Thus, unlike hand-controls that can be purchased in many areas, foot-controls are difficult to obtain. Furthermore, to compound the problem, most rehabilitation counselors are unaware of the existence of foot-controls and erroneously assume that those individuals with upper extremity limitations affecting the use of the arms cannot drive. It took me fifteen years to locate the man in California who equips cars in this fashion. Similarly, it is difficult oftentimes, for people who use wheelchairs to find the right type of adaptations in order to drive. A graduate that I had worked with at Southern Illinois University had obtained a job in Michigan. He desperately wanted to be able to drive so that he could relocate to Michigan and drive independently to his work site. The graduate had severe Rhumatoid Arthritis and was unable to raise his head off of his chin. Likewise, he could not afford a van and he was unable to navigate a wheelchair into the back of a car. Together we worked on resolving this problem. We located a company that manufactures what is called "The Car Top Carrier." This ingenious device raises the wheelchair to the top of the car and compactly folds the chair into a compartment that is attached to the top of the car. The power needed to operate this device is less than the power required to operate electric windows on an ordinary vehicle. The biggest difficulty in enabling this graduate to drive was the limited scope of vision he possessed because of the awkward position of his head and neck. He had no peripheral vision whatsoever. After contacting an imaginative engineering professor employed by the university, a solution was found to correct the visibility problem. A series of enormous mirrors were categorically positioned around the car which enabled this graduate to see approaching automobiles from every different angle. As a result of these adaptations, this disabled individual has been able to gain greater independence and has been able to maintain professional employment.

After reading an article in the summer 1978 issue of Accent on Living, another graduate that I worked with who had Arthrogryposis Congenital, was able to learn to drive. The article pertained to an engineer from the state of Pennsylvania who had come up with a unique method to enable severely disabled individuals with Arthrogryposis to learn to drive. The controls, which comprised a complex system of switches, could be operated by using head motions and chin operations. A steering wheel was drastically reduced in size and mounted on the floor.[6] This graduate now drives all around the city in which he lives and back and forth to work each day. The cost of these controls was a phenomenal $20,000. The price of independence can be high.

Space age technology is here today for those individuals who are lucky enough to be able to afford it. As more severely impaired persons are able to drive independently, the transportation problem will diminish. Employment prospects will be a more feasible and attainable goal. Imagine a vehicle that could be programmed to obey voice commands. Impossible? Maybe in the near future? Wrong on both counts. The technology exists right now. In 1983, the Nissan Motor Company, a major Japanese car maker, announced that it had a computerized, voice-activated passenger car for physically impaired individuals. It was designed for drivers with upper extremity limitations. At the vocal command of the driver, the computer can operate windshield wipers, windows, outside mirrors, and adjust the drivers' seat position. The price of the computer system was estimated to be about $4,400. The steering and braking system are accomplished by foot-controls.

Many high level quadraplegics find the applications of environmental units a godsend at home and on the job. These units perform an array of functions by voice command. Turning on lights, answering the phone and operating other appliances by voice command enables severely disabled persons to function with greater independence. Realizing the benefits that can be derived through computer technology, numbers of people with disabilities are exploring the potential of personal computers. Unquestionably, society is becoming increasingly engrossed in computerization. To meet the growing demand for computer applications for the physically impaired, COPH-2, a consumer organization, came into existence. COPH-2 is an outgrowth of the Illinois Congress of Organizations of the Physically Handicapped. It has a membership of over 400 members from more than 40 states. It offers no-charge computer loans, low cost personal computer adaptations, free technical assistance, networking with members, and a quarterly publication. COPH-2 is enriching the lives of individuals with disabilities by providing concrete "hands on experience"[7] for its members. In the years to come, virtually every career will require some knowledge of computer applications.

The physical act of communicating is so very vital in our daily lives that it becomes almost inconceivable to the average person to comprehend the overwhelming difficulties that must be overcome for those individuals with hearing impairments and speech defects. Employers have been somewhat hesitant to employ deaf persons because of their inability to communicate and use the telephone. Once again, technology has made it possible for deaf and nonverbal persons to function proficiently on the job. Sharp Electronics manufactures a typewriter calculator that retails for

approximately one-hundred dollars that enables disabled persons to type out messages on long strips of paper. Many businesses are installing TTY's so deaf individuals can communicate by telephone. The phone connects to a small computer and the hearing impaired person is able to type and receive messages across a display board.

Cumbersome respiratory equipment once confined individuals with breathing disorders to their homes or to hospitals in order to maintain sustenance. Although much remains to be done in this area, many respirator dependent individuals are able to maintain professional employment by utilizing various types of ventilators that can be attached to wheelchairs. Portable models are also available for individuals who are ambulatory.

The future holds tremendous promise for individuals with disabilities. Scientists are exploring the possibilities and ramifications of biogenetics. Perhaps in the near future it may not be too outlandish for physicians to clone a new body part for one that has become injured. Bionic body parts will be commonplace. Robots will be an integral part of everyday life. Tony Reichelt, President of Quasar Industries, in Rutherford, New Jersey, believes that robots and robotic parts will greatly enhance a disabled person's independence in the future. For several years he has worked on the development of a robotic wheelchair that will be able to assist a disabled person in employment situations and activities of daily living. The robotic wheelchair would feature an arm that could be operated by the user to lift weights up to twenty pounds. It would also be capable of reaching and grabbing various items. Quasar Industries manufactures robots. In the not too distant past, robots were only to be found in popular science fiction novels. Today, robots are being used to sort mail at some large corporations and they even are employed to assemble automobiles. Robotic applications will have a very positive impact on technological advances for the disabled. They may be used as a substitute for a personal attendant. They could help facilitate routine household duties. Perhaps the robot could accompany the disabled person to work and serve as "a reasonable accommodation" on the job.

George Orwell's classic 1984 portrayed a world of gloom and doom with the ubiquitous Big Brother always watching. Optimistically, the future holds new promise for the millions of disabled people of this world. Technology is enabling disabled persons to live more productive and independent lives and to participate in the work force. Hopefully, as the technology becomes more available the cost will not be as financially draining as it is now. Humankind can take comfort in knowing that today's problems are tomorrow's solutions.

FOOTNOTES

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LINKING REHABILITATION TECHNOLOGY TO REHABILITATION SERVICE DELIVERY

Carol J. Whitcraft, Ph.D., Texas Rehabilitation Commission, Austin, Texas
Charles J. Laenger, Sr., Tulsa Rehabilitation Center of Hillcrest Medical Center, Tulsa, Oklahoma 74120

ABSTRACT - Rehabilitation technologies for communication, mobility, and daily living were marketed to rehabilitation counselors and therapists for use with severely disabled clients. Lasting and ongoing linkages were made with the disabled community and the rehabilitation service community including state rehabilitation agencies.

RÉSUMÉ - On a présenté des techniques de réadaptation concernant la communication, la mobilité et la vie quotidienne à des conseillers et des thérapeuthes traitant des personnes gravement handicapées. On a établi des mécanismes pour assurer une liaison continue et durable avec les handicapés et les services de réadaptation communautaires, y compris les organismes gouvernementaux.

The Problem

The National Institute of Handicapped Research addressed the question by funding a utilization project in 1977 to the Texas Rehabilitation Commission with a stipulated subcontract for services to Southwest Research Institute in San Antonio. The project had the working title of IMPART which was an acronym for Innovative Matching of Problems to Available Rehabilitation Technology.

The problem is clearly not the research and development of rehabilitation technologies, but the linking of sources of technology and devices to solutions for the unique problems faced by the individual handicapped persons in their environments of work, education and daily living activities. Implicit in the linking process are the questions of utilization and financing.

Methodology

Management By Objectives (MBO) was the style used to implement the IMPART mission of technology utilization. Five key result areas guided the activities of the program. They were as follows:

- -needs identification
- -identification of research, development and demonstration resources
- -linking needs to research
- -dissemination of results
- -referral of problems

This paper addresses the key result area of linking. The staff of the Texas Rehabilitation Commission employed by IMPART were officed with the Rehabilitation Engineering staff of South-West Research Institute. A rehabilitation professional counselor marketed the IMPART Project to colleagues in rehabilitation offices across Texas and in other states. The marketing aspect included the use of a van to transport equipment to many of the outlying offices and to develop seminars in large metropolitan areas for rehabilitation and medical personnel in that region. The project was described as a resource service and the role of the staff was subordinate to that of the rehabilitation problem originator. The strength of this approach was the availability of third party funds to purchase the technological solution recommended. When the counselor and the project staff had consensus with the disabled person that the technology was appropriate, the counselor used rehabilitation service funds to make the purchase in many instances. Where agency funds were unavailable, devices were bought by individuals, insurance companies and via fund drives.

Linking Activities

Over a five-year period, a total of 1,180 problems were submitted to the IMPART staff by rehabilitation counselors, medical personnel, other professionals, educators, and consumers. Approximately 1,015 solutions were recommended at an average cost of about $838 per solution including administrative costs. The critical elements of the model for transferability are (1) the involvement of trained rehabilitation counselors as staff to market the project, (2) the involvement of rehabilitation engineers as consultants to modify solutions for the problem, (3) the availability of rehabilitation service funds or other third party money to purchase the agreed upon solution, and (4) the subordination of the professional opinions to the acceptance of the disabled person for the solution.

Texas Rehabilitation Commission cross-trained a vocational rehabilitation counselor who acquired experience and demonstrated expertise as a "practical rehabilitation engineer". This man worked in the office and in the field with registered professional engineers - legitimate rehabilitation engineers - for almost four years. He proved to be extremely effective; he was loyal and knew the agency policies, and had the trust of fellow vocational rehabilitation counselors. This was a "precedent-setting" experience which other states should consider emulating; Montana, North Dakota,

Colorado, Utah, New Mexico, and others have expressed interest.

Texas Rehabilitation Commission also trained an information specialist and developed an extensive rehabilitation technology information system. Upon termination of IMPART, Texas Rehabilitation Commission transferred their technology office to their headquarters in Austin where it continues to function today.

Oklahoma permanently employed a rehabilitation engineer in their O'Donoghue Rehabilitation Center and further, contracted with Tulsa Rehabilitation Center for additional rehabilitation engineering services. Tulsa Rehabilitation Center, much impressed by effectiveness of technology service linkages introduced by IMPART, employed a rehabilitation engineer and established a program which continues to flourish. The Tulsa Rehabilitation Center serves the rehabilitation needs of the Oklahoma Department of Mental Retardation, Special Education of Tulsa County Schools, insurance companies, private rehabilitation companies and other hospitals in the area.

Case Studies

Accounts of many cases where technology linkages were vital have been presented and published. See the references listed herein. Additional case studies follow:

Case 1. Marilyn Hoggatt-Graduate Student - A C-5 Quadriplegic

This delightful, ambitious, young lady acquired a batchelors degree in psychology at Northeastern Oklahoma State University. Mother of a nine year-old son, she became quadriplegic due to a fall while extracting a toy from a tree.

Figure 1. Ms. Hoggatt writing text with the Apple computer and NUCDC program and interface. Note "puff-sip" wheelchair control in foreground.

The rehabilitation engineering staff at the Tulsa Rehabilitation Center first met Ms. Hoggatt in intensive care at Hillcrest Medical Center. She rejected nurse call and T.V. control devices demanding control of a page turner so she could "study for final exams" in her graduate courses in counseling psychology.

Oklahoma Rehabilitative Services readily recognized her vocational potential and accepted her as a client. Ms. Hoggatt evaluated several environmental control devices including Prentke Romich, BSR, and the NUCDC Apple computer-based system. She determined that the Northwestern system best suited her short-term and long-term needs.

Figure 2. Ms. Hoggatt demonstrating to her psychology professor that she can perform her old teaching job!

Her university was not immediately convinced that she was capable of completing her graduate training and re-assuming her part-time jobs as teacher and worker in the registrar's office. Tulsa Rehabilitation Center personnel transported this patient/client to her university and helped demonstrate to her professors that she could, indeed, successfully perform as student/student-teacher/faculty member. Progressive members of the teaching and administrative faculty of Northeastern Oklahoma State University accepted Ms. Hoggatt and she returned to her position of student/student-teacher, where she is performing very adequately.

Oklahoma Rehabilitative Services paid for a MED Quad Wheelchair, Apple IIe computer with NUCDC interface, page turner, and BSR environmental control equipment. Her imaginative and competent counselor will surely register a 26-closure for this case.

Case 2. Don Fulk - A Fully Employed Deaf Quadriplegic

A thirty-five year old, prelingually deaf quadriplegic was successfully vocationally rehabilitated by collaborative effort of Oklahoma Rehabilitative Services, IMPART, Lowrance Electronics, Inc., and the Tulsa Rehabilitation

Center. Administrators of Oklahoma Rehabilitative and Visual Services (OR&VS) accepted and served this individual who is now a productive member of society. This case was reported to RESNA in 1982.

Figure 3. A determined deaf-quadriplegic who drives and works full-time.

Mr. Fulk continues as a successful electronics assembler. Much of his success is attributable to an excellent vocational rehabilitation counselor, an informed and proficient personnel administrator, and the volition of the client himself. These people, and Oklahoma Rehabilitative Services, represent perennial linkages.

Case 3. Vocational Rehabilitation of a C-2 Quadriplegic

Ray Murphy became a C-2 quadriplegic thirteen years ago. This case was reported to RESNA in 1983. He and his family were unaware of the independence that technical devices can bring, so he was unable to exert any control over his environment for eleven years.

Today he effectively operates an environmental control system, powered wheelchair, and Apple II computer with puff-sip control. He is now a client of the Oklahoma Department of Rehabilitative Services and is continuing studies in computer science at Tulsa Junior College. He attends class in a MED "Quad" puff-sip wheelchair. One day soon he will become self-employed as an income tax consultant or sports statistician. This case exemplifies linkages between the technological community, a state rehabilitation agency, and the disabled community.

Case 4. Efforts to Rehabilitate A Severely Cerebral Palsied Man

George Barnosky is a 41 year-old athetoid, cerebral palsied man, who goes backward in his wheelchair. This lovable man had never written his name. Tulsa Rehabilitation Center invited him to use the Apple computer (NUCDC program) to develop the capability to write. George destroyed at least 40 switches with his untamed arms, but with weeks of patience of staff and volunteer support, Mr. Barnosky learned to control two switches and the Apple computer.

Figure 4. Mr. Barnosky goes backward in his manual wheelchair.

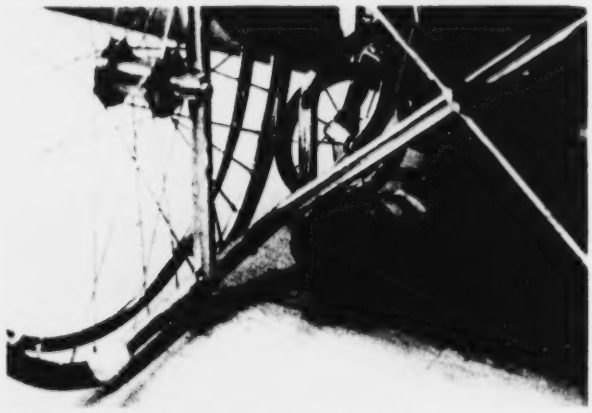

Figure 5. He wears out shoes rapidly.

He can now write his name and control his environment with the aid of an NIHR-developed environmental control system. With the aid of volunteers, and utilization of the computer, this intelligent, but deprived man is learning to read and write. He is also learning to go forward in a manual wheelchair coupled with an Amigo Hitchhiker. Eventually, Mr. Barnosky may develop enough vocational potential to enable Oklahoma Rehabilitative Services to accept him as a client. Linkages of technology-based services with agencies, rehabilitation centers, and volunteers will have initiated this action.

Post-IMPART or Ongoing Linkages

An IMPART-like program continues at Texas Rehabilitation Commission. This office is manned by an experienced, cross-trained vocational rehabilitation counselor who serves as a "practical" rehabilitation engineer. Demonstration rehabilitation devices acquired during IMPART are maintained and used in the manner established during the program. These devices are loaned to counselors and clients; some have

been loaned to disabled individuals and service personnel in neighboring states. Texas Rehabilitation Commission continues to maintain linkages with ABLEDATA, Southwest Research Institute, Tulsa Rehabilitation Center, and other sources of technology.

Oklahoma continues to support it's rehabilitation engineering program at O'Donoghue Rehabilitation Center in Oklahoma City. Oklahoma also purchases rehabilitation engineering services from the Tulsa Rehabilitation Center. The Rehabilitation Engineering Department at the Tulsa Rehabilitation Center continues to flourish and serves the Oklahoma Department of Mental Retardation, Tulsa Developmental Center (for severely disabled grade school children), Tulsa Center for the Physically Limited, and other hospitals and nursing homes. This group has combined with Hillcrest Medical Center's Biomedical Department, which significantly improves the strength of the rehabilitation engineering program.

Since termination of the IMPART program, exteam members have presented vocational rehabilitation engineering workshops in several states. Vocational rehabilitation counselors from Colorado, Utah, Texas, and Oklahoma have visited the Tulsa Rehabilitation Center, where they participated in workshops and internship programs in rehabilitation engineering. After returning to their home states, these and other personnel have interacted with the Tulsa Rehabilitation Center in solving rehabilitation problems through technology utilization.

CONCLUSION

The IMPART program established ongoing linkages between technological sources and service delivery personnel and agencies. The impact of this program continues as is evidenced by recent case studies and ongoing collaborative problem-solving ventures and information-sharing. Indeed, these firm linkages continue to grow and serve as examples to other state agencies.

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Vocational rehabilitation counselors, the life blood of comprehensive rehabilitation programs, have incorporated technology into services that they deliver. With their ongoing support, vital linkages will survive in these states.

SPECIAL SESSION/SÉANCE SPÉCIALE 8

PROSTHETICS AND ORTHOTICS/

PROTHÈSES ET ORTHÈSES

Chairperson/Président:

G. Fernie
West Park Hospital
Toronto, Canada

THE STATE OF THE ART OF PROSTHETICS AND ORTHOTICS

R.M. Davies, Bioengineering Centre, University College London
London, England SW15 5PR

ABSTRACT - Current practices in prosthetics and orthotics are based on the traditional approach of the artisan. Fundamental changes in routine practice can be expected with the emergence of structurally sound thermoplastic materials whose characteristics can be optimally controlled to achieve a swift supply of bespoke, lightweight, structurally sound appliances.

RÉSUMÉ - Les pratiques actuelles dans le domaine des prothèses et orthèses sont fondées sur l'approche classique de l'artisan. On peut s'attendre à des changements fondamentaux dans la pratique usuelle avec l'apparition des matériaux thermoplastiques sûrs du point de vue structural dont les caractéristiques peuvent être contrôlées de façon optimale pour obtenir rapidement et en quantité des dispositifs sur mesure, légers et sûr du point de vue structural.

INTRODUCTION

There are useful starting points in the literature (1,2) for anyone who wishes to review the fields of prosthetics and orthotics. The contributions of engineers in the work, however, include production and distribution along with research, evaluation, education and patient service. This tendency of engineers to seek general solutions for populations is sometimes at odds with medical priorities which require an immediate solution of a particular patient's problem. My colleagues in Vancouver(3) have discussed this difference and noted that "medical people see the patient as a problem whereas engineers see the patient as an example of a problem". A consequence is that the engineer's action period is frustratingly long by medical time standards. These differences need to be recognised and accommodated by all concerned so that teams can be formed to uncover real solutions which exploit the potential of modern technology. And new specialists need to be attracted to provide expertise in plastics, metals, electronics, computers, etc.

A valuable contribution is the exploitation of modern thermoplastic materials in controlled and automated manufacturing processes to rapidly produce inexpensive and lightweight prostheses and orthoses. The challenge is predominantly in engineering advances, interfacing with biological areas of application. In addition to establishing a sound objective basis which lays the ground work for technological advance, the practical results can effect a considerable improvement in the treatment of patients and reduction in cost and delivery times.

PROSTHETICS (4)

This field is "technological" in that it involves making and using machines. It differs from other technologies in that prostheses must also interface intimately with the owner in a strongly interactive way including force and motion interactions. Technology can be employed to improve the quality of prostheses and at the same time improve the delivery.

The processes used for the construction of prostheses have their roots in artisan methods. The harness maker, the aircraft metal worker, the cabinet maker and the armourer have left their mark. Workers in the field were often wearers of devices themselves. These people were innovators by nature often, basing their ideas on their original arts or on the needs they wished to satisfy as wearers.

At the moment, to provide a prosthesis for a below-knee (BK) amputee, simple measurements are taken, a plaster impression is made, a model of the stump is made, the stump model is modified and becomes the mould over which the socket is fabricated. Cosmetic restorations are done by manually sculpting the medium used. Results thus obtained are not reproducible by a particular operator and are usually quite variable between operators. New operators require years of training and experience to raise them to such proficiency as is attainable.

Since 1945 research organisations have played a major role in the development of improvements. They have engaged in the formulation of new information, systematization of artisan practices, the development of tools, devices and techniques and the introduction of new materials. The formulation of new information must continue but the technologies which have emerged during the past few years make further refinement of artisan methods inappropriate.

The moment is ripe for the introduction of radically different methods.

A five-module modern alternative has been developed in a collaborative programme encompassing teams in Vancouver, Toronto and London. This is the first time such a capability has been available. The system includes:

1. A SHAPE SENSOR which can measure the residual limb and sound limb as a basis for production of the prosthetic socket and cosmetic shape; 2. A COMPUTER AIDED DESIGN process which permits modifcation of the shape to the bio- mechanical requirements and delivery of the shape data to a carver; 3. NUMERICALLY CONTROLLED CARVER tailored to the field; 4. The well proven RAPIDFORM process which can produce a thermoplastic socket in 20 minutes; 5. A ROTATIONAL MOULDER which permits rapid fabrication of structural components out of plastic on site. The key factors in this modern alternative include microprocessor control and tailored materials. What this means is that predictable shapes can be sculpted and predictable shape-components can be fabricated. Data collected may be stored and reused.

The whole field is on the threshold of sweeping improvements which have not been possible in the past. The bespoke nature of each patient's requirements can now be met by the radically new methods being reported at this meeting. The scope of these changes range from defining patients' requirements through all stages of fabrication and all levels of amputation. The artisan's methods are being overtaken by new systems of supply which are scientifically based, semi-automated and computer controlled.

ORTHOTICS

The disabilities which may be treated effectively with orthotic appliances fall broadly into two categories:- firstly weakened or paralysed muscles as in stroke or poliomyelitis for example, and secondly unstable joints as in rheumatoid arthritis, ligamentous injury etc. The total number of patients who could benefit from effectively designed and prescribed orthoses is very large (a factor of 10 greater than for prostheses). In approaching these problems there are a number of constraints (spatial, kinematic and kinetic, structural) which are imposed on orthotic designs because of the anatomical wholeness and physiological weakness of the patients.

Colin McLaurin(5) pointed out that "a few years ago orthopaedic appliances could be described in terms of special footwear, long and short leg braces, spinal and cervical braces, wheelchairs, crutches and some rather complicated upper-limb orthoses." The scope has now broadened to include vacuum formed thermoplastic appliances, pneumatic braces, electrical stimulation and feedback, special seating, footwear and mobility advances, etc. The new ideas call for different thinking by the physician and orthotist, different expertise in fitting and fabricating, and expensive capital equipment for moulding the new materials. To illustrate the impact, I will take as examples some of the new ideas in body support and foot support.

There is a continuing emphasis on the postural support problems of severely disabled children. Their possibilities are enhanced and their problems reduced by correct seating and trunk support. A number of solutions are being explored in order to provide the above benefits and to avoid further complications such as tissue breakdown resulting from unhealthy or uneven support. With each patient requiring a completely individual system and large numbers presenting, the engineering approach has been to think modular - and indeed it is a modular approach which is showing the greatest promise.

A shapeable matrix body support system used for seating is now available at a price equivalent to that of moulded seats. However, it is estimated that over a five year period a saving of 300% will be achieved over the moulded process because the matrix is re-shapeable. Commercial delivery times are about three weeks and the quality of fit is good because one can see and feel through the matrix during fitting and delivery.

Special insoles and orthopaedic footwear are often provided for hospital patients through the services of an on-site orthotist or chiropodist. This person is called on to provide solutions to many different foot support problems dictated by diverse medical conditions. The initial stage of provision is an assessment of the possibilities for correction by foot support. Appropriate footwear is then either fabricated on site or a customised product from a commercial company is requested.

This system of provision leans heavily on the skills of the individual orthotist both to prescribe and supply the required item. The frequent need to request bespoke footwear to be manufactured leads to delays which may be costly in delayed rehabilitation of the patient or even worse, in medical deterioration necess- itating surgical intervention. In many instances specification of corrective footwear must take into account the functional requirements of the lower limb and even the whole body.

It is technologically possible to employ semi-automated processes, which can systematically reproduce the foot shape, build in controlled rectification and alignment, and manufacture the footwear reproducibly with consistent quality. The requisite stages of shape measurement or duplication, rectification and alignment are common to both foot orthoses and leg prostheses. The potential advantages of a semi-automated system are: consistency, ability to control specification, speed of production which reduces the cost of repeated patient visits, potential to store patient data instead of storing bulky casts or lasts, and low-cost production.

There is, of course, a great deal of work addressing the problems of bipedal support, particularly concerning the factors disrupting the ability to stand and ambulate, and concerning techniques to assist or re-establish these skills. Forces and pressures at the interface between the foot and the ground reveal information about the structure and condition of the foot and about the biomechanics of the whole body as reflected by the loads transmitted. The utilization of this information leads to applications in surgery, footwear design, lower limb prostheses and orthoses, retraining of balance in stance and gait, etc. A large number of techniques have been developed and are being used in these aspects of rehabilitation. Other important developments in rehabilitation are in areas such as wheeled mobility and electrical and electro-tactile stimulation. These advances interface and overlap other areas of work.

TECHNOLOGY TRANSFER

Commercial uptake of the results of research in the prosthetic/orthotic fields is unsatisfactory. This occurs because of the cost of supplying diverse bespoke and "standard" products in a small, geographically dispersed market. Therefore there is little industrial R and D and a very heavy reliance falls on University and Medical Physics research which in turn is constrained by the existing commercial base. This unique market combined with a limited relationship between research and commercial areas has resulted in the loss of many products for the consumer and a reduction in benefit to cost ratios for the research centres.

In this context John Lyman(6) has pointed out that market potential "has been a problem for many potential applications for the handicapped as the markets have not provided sufficient economic justification for the transition from research to manufacturing. Hearing aids, heart pacemakers, portable kidney dialyzers and soon, automatic insulin delivery systems (artificial pancreas) have very large markets and hence have been developed and manufactured. All are based on specialised microelectronic devices. Yet there are many other prosthetic and function aiding devices that have not left the research stage or even begun it because of lack of market potential."

It needs to be appreciated that the problem of TRANSFER of new technology from the university environment to the production/distribution environment has NOT been adequately solved. When there is little known as to the validity of a particular design because of its radical nature, the problem of transfer is even more acute. Such a product needs the drive which can be generated by the committed developer, and developers with such drive are needed by the research institution. Since these people are central to both research and marketing, schemes will need to evolve which permit and encourage their smooth transfer between the two functions according to agreed priorities. Thus their energies can be tuned to their motivation to see the product used and to continue development of new products.

CONCLUDING COMMENT

Many possibilities emerge from developments which parallel those in prosthetics and orthotics. Environmental control devices which have existed for many years permit switching functions by breath or body movement to control, for example, lights, typewriters, telephones and other equipment. However, dramatically increased possibilities are offered by introducing computer logic and these possibilities then begin to overlap with the fields of robotics and machine intelligence. We are not far away from speech recognition by machine and thus from voice-actuated typewriters. According to Dr. Archie Bowen of Carleton University here in Ottawa, these developments will result in a gigantic equalization. "Since these machines will be intellectual machines, the problem will not be differentiation between physical handicaps and none, but between ability to participate in a whole new environment or not."

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LEFT TO OUR OWN DEVICES: DEVELOPING WHEELCHAIRS IN THE DEVELOPING WORLD

Ralf Hotchkiss, Appropriate Technology International, Washington, D.C.
Omar Talavera, Organizacion Des Revolucionarios Deshabilitados, Managua, Nicaragua
Danny Pipo and Jess Decot, Tahanan Walang Hagdanan, Manila, Philippines

ABSTRACT - The need for strong, lightweight folding wheelchairs, similar to those popular among U.S. farmers, is great in developing countries. Because of the high cost of these chairs, less functional chair designs have been chosen for fabrication and use in most developing countries. Over the last three years we have combined old and new ideas to come up with a chair which can approach the versatility and durability of the best of chairs, but at a very low cost. Our chairs are being manufactured in Nicaragua, the Philippines, Paraguay and Malawe, and parts of the design have been adopted elsewhere. We hope to establish lines of communication to enable makers of these chairs to share new developments.

RÉSUMÉ - Le besoin pour chaises roulantes pliables, fortes et légères comme ceux qui sont populaires parmi les fermiers des états-unis, est grand dans les pays en train de développement. A cause du haut prix de ces chaises, les desseins moins fonctionales etaient choisi pour la fabrication et l'usage dans la plupart des pays. Pendant les trois dernières années, nous avons combiné des vielles idées avec des nouvelles idées pour arriver à une chaise roulante avec la versatilité et la durabilité des meilleurs chaises mais à un prix très bas. Actuelment, nos chaises roulantes sont fabriqués aux Nicaragua, les Phillipines, Paraguay et Malawe et quelques parties du dessein ont été adopté autre part. Nous espèrons à établir les lignes de communication pour permettre aux constructeurs de chaises roulantes à partager des nouveaux développements.

Our wheelchair project began in 1980 when disabled activist Bruce Curtis asked Ralf Hotchkiss to visit Nicaragua and provide Technical Assistance to a group of disabled people. One of the people they met there was co-author Omar Talavera, who since has become the Nicaraguan group's principal wheelchair builder and designer.

The Nicaraguan Disabled People hoped to set up a wheelchair repair shop in which they could eventually build new chairs close to today's state of the art. The Nicaraguans needed chairs which would enable them to live more independently, use buses and taxis, and seek education and employment.

In 1981, Approprate Technology International contracted with Ralf Hotchkiss and the group in Managua to develop a durable folding wheelchair suited to the needs of disabled people in the developing countries of Latin America. John Guy Smith, ATI's Latin American chief, proposed to develop the technology to assist small businesses in producing quality wheelchairs efficiently with a minimum of capital investment.

LOW COST PROSTHESES

Considerable development of low cost prostheses has been done by Frères Raymond and Pierre Jaccard. Omar Talavera studied the making of their prostheses in Thailand, and found that quite serviceable prostheses could be made in a short time of wood, bamboo, leather, and mild steel.A copy of their book, Prothese Africaine, is available in French or English from:

Raoul Follereau
33 Rue de Dantzig; 75015 Paris; France

Thelma Ayala, Nicaraguan wheelchair maker

Under this contract prototypes have been built in Nicaragua, the Philippines, at the Hesperian Foundation in Ajoya, Mexico, in Singapore at the world meeting of Disabled Peoples' International and in a workshop in Jamaica attended by mechanics from Latin America and Africa.

Disabled people in developing countries have difficulty finding wheelchairs that are affordable and that meet their needs. Most of the wheelchair riders have only been able to obtain hospital-type

chairs with hard tires, and without removable armrests or footrests. These chairs, many of which have been donated by wealthier countries, are poorly suited to active use.

Active wheelchair users in developing countries can run into the same problems as active users elsewhere. When wheelchairs are used heavily, for example to climb curbs or follow rocky trails, they bend and break if they are not properly reinforced. When chairs are propelled over rough ground, they lose traction if they do not have pneumatic tires. If wheelchairs don't fold they will not fit easily in the aisle of a bus or on the side of a donkey.

Any new design should be compared to the present standard chair to be sure the new chair will fill the minimum needs of its users. The most important areas for comparison are:

CHARACTERISTICS OF THE STANDARD WHEELCHAIR

* OVERALL WIDTH: 23-24 inches for a chair with a 16 inch wide seat.
* OVERALL LENGTH: 42 inches
* WEIGHT: 42 to 48 pounds fully equipped.
* TRACTION: Weight is shifted to the rear drive wheels during acceleration, giving good traction over rough terrain.
* EASE OF ASSISTANCE: The chair can be tipped back on the large rear wheels by an assistant and pushed or pulled over rough terrain.
* ABILITY TO FOLD: The chair folds to a width of 12 inches or less.
* ACCESS TO DESKS AND WORKTABLES: The chair, equipped with desk type armrests, allows the rider to pull the chair close to a table.
* LATERAL TRANSFERS: The chair, equipped with removable armrests, allows the rider to slide sideways in and out of the seat. This is very important to riders who cannot stand.

The Nicaraguan and Philippine groups of wheelchair riders have used many different configurations of wheelchairs, including three- and four-wheeled models with the large wheels both at the front and at the rear. Of these, they have found only one model which fully meets their needs, and they will settle for nothing less. This is a heavy duty chair with pneumatic bicycle wheels on the rear and wide caster wheels on the front.

This type of chair is used in the U.S. by disabled farmers and others who must be mobile in rural or snowy environments. For heavy mud and snow, they sometimes add tire chains. Many also use removable armrests, swing-away footrests, and other features to enable them to function independently.

EVOLUTION OF OUR DESIGN

The A.T.I. sponsored project began in 1981 in Managua, Nicaragua in the offices of the new Independent Living Center that had been established by disabled Nicaraguans. The first wheelchairs began to be produced in that year.

The economic situation in Nicaragua made it difficult, and sometimes impossible, for the wheelchair shop to purchase custom-made wheelchair parts from outside the country. We were forced to find ways to make most of the wheelchair components out of standard Nicaraguan hardware. We are still looking for ways to make a highly resilient, low cost front wheel, but everything else is now made of materials which are usually locally available.

The lack of availability of parts in Nicaragua quickly began to dictate the design of our wheelchair. Our design changed as we discovered what was not available: hardened bolts, concentric tubing sizes, suitable ready-made hubs, and more.

In our first design we used a wooden seat as part of a simpler and stronger folding mechanism. We had problems with the wooden seat, though, because few of the Nicaraguans use wheelchair cushions. The bare wooden seat would give pressure sores to people with spinal cord injuries.

During the first year the members of the Berkeley based Disabled International Support Effort brought cushions for some of the Nicaraguans. As the cushions wore out and needed replacement, it became clear why most Nicaraguans would never use cushions - they can't afford replacements. The customary canvas sling seat of standard wheelchairs is more forgiving, so we adapted our chair to use it.

PHILIPPINE WHEELCHAIRS

Visits to Tahanan Walang Hagdanan (House With No Stairs) in the Philippines by Hotchkiss in 1981 and Talavera in 1982 resulted in a significant change in our approach. Tahanan has a wheelchair shop composed of 22 workers, all of whom build and use their own wheelchairs. Tahanan has produced over 1000 lightweight folding wheelchairs during the past 6 years. They have made up to 50 chairs a month when sufficient materials were available.

Their product line consists of a complete selection of folding wheelchairs for prices ranging from 1000 pesos to 2500 pesos, or about $125 to $313 (U.S.) before last year's devaluation.

PHILIPPINE COST ANALYSIS

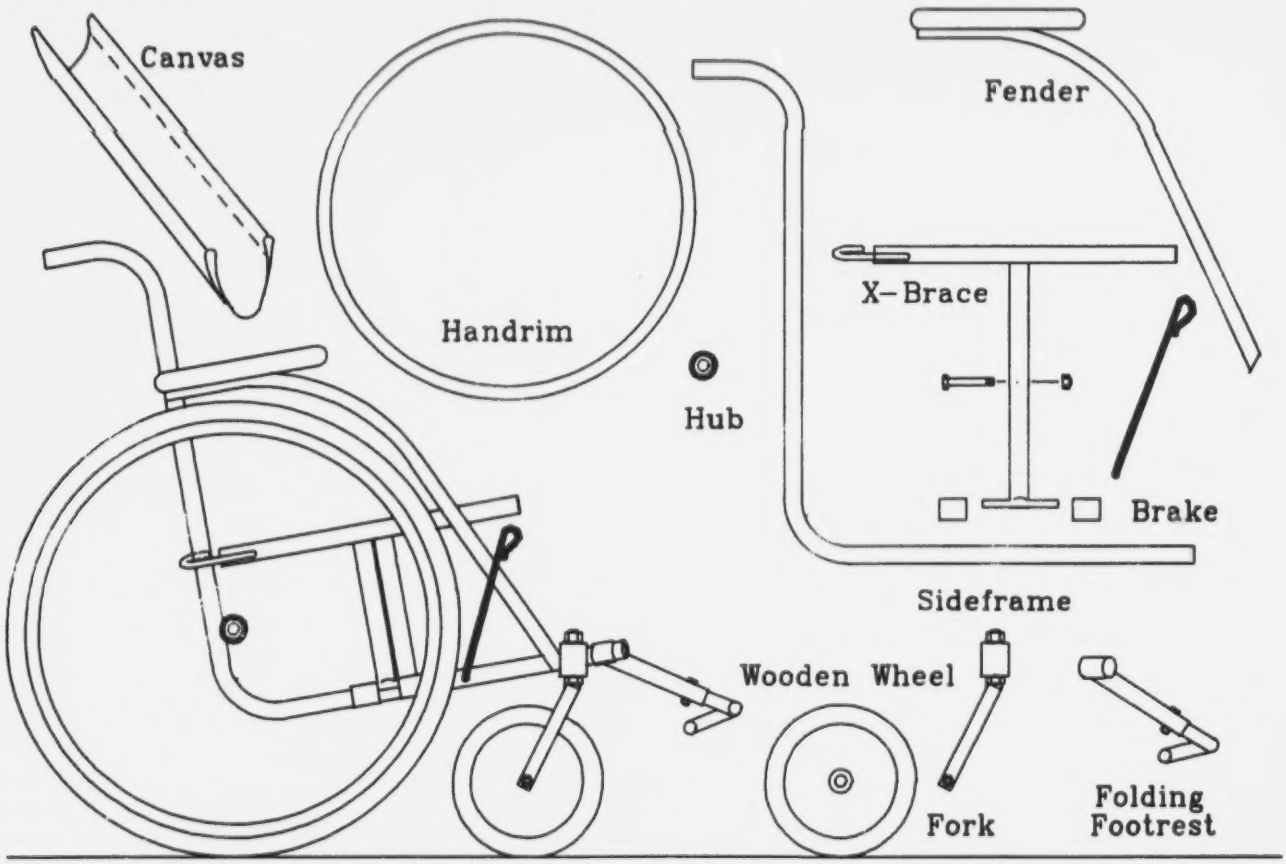
Danny Pipo of Tahanan has done detailed time and materials analyses of each model in the Tahanan

WHEELCHAIR COST BREAKDOWN

at Tahanan Walang Hagdanan, Cainta, Philippines

OPERATION	LABOR	MAT'LS	TOTAL
CHASSIS FABRICATION -	26 hrs.=$12.90	+ $ 6.77	=$19.67
FILING, SANDING -----	7 HRS.=$ 3.77	+ $ .00	=$ 3.77
PAINTING (subcontracted) ----------		+ $ 6.25	=$ 6.25
CHROME PLATING (Optional) $18.			
FRONT CASTER WHEELS -	6 hrs.=$ 3.23	+ $ 5.85	=$ 9.08
REAR WHEELS ---------	5 hrs.=$ 2.69	+ $22.50	=$25.19
HANDRIMS ----------	1 1/4.=$ 0.56	+ $ 0.73	=$ 1.29
FOOTRESTS ----------	2 hrs.=$ 1.08	+ $ 9.00	=$10.08
REMOVABLE ARMRESTS --	3 hrs.=$ 0.83	+ $ 1.03	=$ 1.86
BRAKES ----------	35MIN.=$ 0.26	+ $ 0.20	=$ 0.46
UPHOLSTERY ----------	1 1/2.=$ 0.81	+ $ 4.38	=$ 5.19
COMPONENT INSTALL'N -	21 hrs.=$11.29	+ $ 6.27	=$17.56
FINISHING AND MISC. -	10 hrs.=$ 5.38	+ $10.11	=$15.49
TOTAL	50 1/3hrs.=$42.80	+ $73.09	=$115.89

APPROPRIATE TECHNOLOGY INT'L WHEELCHAIR



line. One of the most striking facts Danny has shown is that the cost of the complete frame of the chair is only about 1/3 of the total cost of the chair. The remaining cost is that of making and installing the components: the wheels, hubs, forks, handrims, brakes, footrests and upholstery. Since the components make up most of the cost, we decided they deserved most of our attention.

The costs at Tahanan for one of their lower cost chairs, converted to U.S. dollars before last year's devaluation, were as follows. The costs shown for direct labor include overhead of about 140% of the median wage, and the hourly rate varies according to the skill level of the craftsperson.

The chair which Danny analyzed is similar to a typical commercial folding chair. Because of the complexity of the chair, it takes a long time to make. The Tahanan prices are low and their quality reasonably high, but that is only possible because the skilled workers pay themselves at a rate less than half the Philippine minimum wage.

Jess Decot, the Shop Director at Tahanan, hopes to be able to both cut the prices and raise the wages using the new component designs we have developed. Just staying in business, however, will be quite a feat in the immediate future; the recent devaluation and shortage of imported bearings, tires, and other components have made both production and sales exceedingly difficult.

OUR CURRENT DESIGN

Our chair now comes very close to the original goal of providing the advantages of the best of chairs while approaching the price of the cheapest. It is the functional equivalent, for users with the most common types of disabilities, of the higher-priced import's. It weighs 25% less than most comparable chairs. The cost is about $60 to $80 (U.S.) for materials plus labor and overhead for a week of work by one skilled mechanic.

Our design bears a striking resemblance to the Everest and Jennings and American Wheelchair Company models of the early 1940's. We have in fact gone back to many of the fabrication techniques developed by the early wheelchair and bicycle makers.

Our frame uses a simple tubular design with a slung canvas seat. It folds with a single tubular x-brace. It differs from the current commercial chairs primarily in how we have dealt with the need for removable armrests and swing-away footrests.

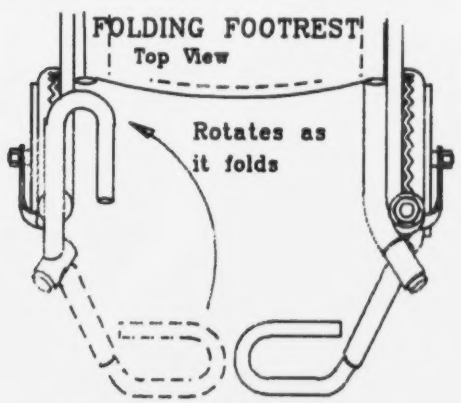
ARMREST DESIGN

The early folding wheelchairs of the 1930'S and 40'S required a high, square armrest to accomodate the folding mechanism. That armrest design made it difficult for users to sit close to tables, and also made it difficult for many users to transfer in or out of the chair.

The development of the removable desk arm was

a great improvement. The desk arm made it much easier for users to work effectively at tables. Transferring from chair to chair also became much easier when the armrest was removed and placed out of the way. The problem with the removable desk arm has been that it complicates the design of the chair's folding mechanism. Telescoping tubes and extra reinforcement have to be added to the chair, increasing the cost and weight significantly.

We have used a curved fender bar which we first encountered in the Philippines to replace the armrest. Because its shape follows the tire, this armrest does not get in the way of transferring into the chair. If an arm pad and a skirtguard are added to our armrest, it can do the job of a standard removable desk arm, but with less cost and complexity. We have altered the folding mechanism of the chair so that the fender bar can also serve as a structural member of the chair's sideframe, further reducing the chair's weight and complexity.



FOOTREST DESIGN

The swing-away footrest was originally developed to allow maneuvering in very tight spaces and to allow close access for difficult transfers. This feature is often needed in the inaccessable environments of developing countries, yet its cost and complexity are prohibitive. We have developed a swing-away footrest which has half as many parts and weighs half as much as most commercial models.

pounds. Because of this weakness the bicycle axles used on hundreds of wheelchairs in the Philippines are bent so far out of alignment that the wheels constantly rub on the sides of the chairs. It was to correct this and other deficiencies that Tahanan originally started making wheelchairs.

One way to strengthen a bicycle axle is to build a fork around the wheel so the axle can be supported at both ends. Unfortunately this can widen the chair by 2 inches (5cm.) or more, and our groups of users find this unacceptable.

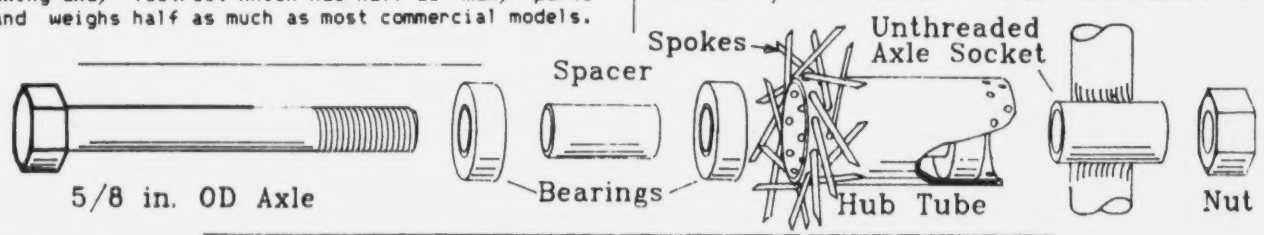
Most commercial chairs use axle diameters of 7/16 inch, 12 mm., or 1/2 inch. Because axles this thin will bend if they are made of mild steel, hardened bolts are used. Because of the possibility that hardened bolts may crack, only aircraft quality hardened axle bolts are used by most manufacturers. Unfortunately bolts of this quality are not available in many developing countries.

5/8 inch diameter bolts, either mild or hardened, can be used without fear of bending in heavy duty wheelchairs. A 5/8 inch inside diameter sealed bearing, around which a hub can be built, is widely available at low cost. This bearing, the 99502h, is used in Ford and Chrysler alternators. Thus the 5/8 inch axle is our choice, at least for countries where the proper bearings are available at a competitive price.

Mild steel metric bolts are available in 14 or 16 mm. diameters, and either of these should be strong enough to be used as a wheelchair axle. Unfortunately there are no standard Metric bearings to fit either bolt size. The closest standard bearing, with a 15 mm. inside diameter, could only be used with a special bolt or a spacer.

We are making our hubs out of straight steel tubing with no end flanges. The spokes are held by holes in the ends of the hub tube. The spoke heads hold the bearings in place. The hub tube can be made in 5 minutes; the material costs $0.20 (US).

Sealed Bearing Hub
Made from 1 1/2 inch tubing with 1/16 inch wall thickness



AXLE DIAMETER AND HUB DESIGN

It has always been difficult to purchase inexpensive hubs and axles which are strong enough to use on a wheelchair. Some designers have used bicycle axles and hubs, with disasterous results. Bicycle axles are usually made of mild steel, and have a diameter of 3/8 inch (9.5 mm.) or less.

The force pushing sideways on the rim of a wheelchair wheel can often exceed 100 pounds (45 kg.). If only one end of a bicycle axle is connected to a wheelchair, the axle can be bent by a sideward force on the wheel rim of only 30 or 40

CASTER FORK DESIGN

Our caster fork is made from a bar of mild steel, bent into the shape of a U and welded to the end of a 5/8 inch dia. bolt. The bar is 1/4 by 3/4 inch or 6 by 18 mm. mild steel.

BENDING TOOLS

We use a standard low cost Hossfeld bender for bending frame tubing and bar stock. We power it with an auto jack to make it easy for disabled mechanics to use. Our handrims are bent on a simple bender made of plywood.

WEIGHT

The overall weight of our chair, fully equipped with brakes, handrims, and swing-away footrests ranges from about 32 to 36 pounds. This is about ten pounds (5.5 kg.) less than comparable commercial chairs. Further weight reduction is possible by using more expensive aluminum wheel rims and molybdenum tubing.

RATE OF PRODUCTION

A single worker in Nicaragua is now producing one complete chair per week. Majid Bakali, an experienced wheelchair maker from Malawi, Africa, showed at our recent Workshop in Jamaica that it may be possible to make a chair in half that time.

DISSEMINATION: OUR FIRST WORKSHOP

In 1983, under the sponsorship of A.T.I., a workshop was held at the offices of the Combined Disabilities Association in Jamaica. Attending were mechanics from Trinidad, Guyana, Paraguay, Malawe, and Nicaragua as well as Jamaica. Each mechanic completed a chair and took it home. Our chair underwent several revisions during the workshop. Participants at the workshop, most of whom already had some wheelchair-making or other manufacturing experience, provided solutions to several of our design problems. Most important, Goerge Kirton of Guyana and Majid Bakali of Malawi made significant improvements in our welding jigs. The new welding jigs help maintain accurate alignment of the wheelchair frames and speed up our production considerably.

A surprising number of improvements resulted from the workshop because of the interaction of:

* Mechanics with personal experience in wheelchair use and modification, coming both from developed and developing countries.
* Tool makers with experience both in high and low capital manufacturing operations.

DOWN THE ROAD: ALTERNATE MATERIALS

It may be possible to construct folding frames of wood which are light and strong enough for heavy use. Chair frames could then be made in shops having only woodworking tools. A metalworking shop would still be needed to supply readymade axle mounting plates, hubs, caster forks, and handrims. If wood serves well, perhaps other materials such as bamboo or rattan have possibilities. We have heard of previous work with these materials and are looking for more information.

Work has been done recently in Australia with making wheelchair frames out of plastic pipe. Adapting our wheels, footrests, handrims and other components to this chassis might result in a more useful and durable plastic chair.

A COMPLETE SELECTION OF CHAIRS

We find ourselves in much the same position as wheelchair makers in the 30's: We have a good base model, but must quickly develop the other options so needed for certain disabilities. Reclining backs, elevating footrests, and other options must be redesigned to fit our chair. Hopefully we can simplify them in the process.

TRICYCLES

Hand powered tricycles are one of the best vehicles for disabled people to cover distances up to a few miles. Unfortunately tricycles don't serve very well indoors. More practical for full time wheelchair riders is a large wheel which attaches to the front of a standard wheelchair for traveling long distances but which can be detached to use the wheelchair indoors.

The best removable front drive wheel we have seen is made by the Unicycle Company of Montreal. The user of this device does not have to get out of the wheelchair in order to attach or detach the tricycle wheel. The Unicycle drive wheel could be adapted to fit most types of wheelchairs.

ELECTRIC POWERED WHEELCHAIRS

As more and more quadriplegics survive in developing countries, the need for reliable, cheap electric powered wheelchairs increases. Reasonably priced electrics are now available from Japan and Brazil, but they still cost too much for most quadriplegics in developing countries.

A detachable power unit for a lightweight folding wheelchair would probably be the most practical approach to this problem. The chair could then be used with or without the power unit. For users who can handle a tiller, the Amigo Hitchhiker, mounted on the front of the chair,is a good example to follow. For more disabled users a rear mounted unit like the Motorette or Damaco is a possibility. Students at San Francisco State University have come up with the intriguing concept of a tiny tractor made to push a wheelchair.

Use of transistorized speed controllers is out of the question because of their high cost and the unavailability of replacement parts.

A quality, cheap electric motor with enough torque to pull the chair through uneven terrain is particularly hard to find. One possibility is an auto generator, with the field rewound to make it into a series motor. The efficiency will not be as high as some permanent magnet motors, but the stall torque will be excellent.

THE IMMEDIATE FUTURE...

We are anxiously awaiting more news from the groups in Malawe, Paraguay, Jamaica, Guyana, and Trinidad. As they adapt the chairs to their local materials, needs, and skills, they are sure to come up with improvements which will help all of us. We will pass these developments on in future workshops and technical assistance visits.

In the meantime we would appreciate any information on lower cost rust protection for the frames and handrims, workable alternatives to commercial ball bearings, methods of making tire rims out of tubing and tubing out of sheet metal, ways to make spokes or resilient 8 inch dia. wheels, and sources of surplus or used sealed ball bearings.

FOR FURTHER INFORMATION:

Contact Bruce Curtis
Appropriate Technology International
1724 Massachusetts Avenue
Washington, D. C. 20036

THE USE OF ELECTRICAL STIMULATION FOR THE TREATMENT OF SCOLIOSIS IN CHILDREN

M.A. Herbert
Hospital for Sick Children, 555 University Ave., Toronto, Ontario M5G 1X8, Canada

ABSTRACT - Electrical stimulation of the paraspinal muscles for the treatment of scoliosis in growing children, has been used clinically for 10 years. Both implantable and surface delivery systems are used. In both systems, the treatment is carried out at night while the patient sleeps, with no day-time bracing or exercise programs used. Success rate for treatment with both techniques is about 85% with excellent patient acceptance.

RÉSUMÉ - En clinique, on utilise depuis 10 ans la stimulation électrique des muscles paraspinaux pour le traitement de la scoliose chez les enfants en croissance. On utilise aussi bien des systèmes implantables que des systèmes agissant en surface. Quel que soit le système utilisé, le traitement est appliqué la nuit pendant que le sujet dort sans que l'on recoure à un programme d'exercices ou à des appareils de soutien pendant le jour. Le taux de succès obtenu avec ces deux techniques est d'environ 85 % et le traitement est très bien accepté par les sujets.

INTRODUCTION

A normal spine when viewed on an X-ray taken from the front to back (AP), should be straight. However in up to 15% of children, there is a lateral (side to side) curvature called scoliosis (1). Of this large number of children, only about 0.3% require treatment because of a progressive curve (2). The rest of the curves never become a serious problem for the child. The cause of scoliosis is unknown at this time, although there are many theories as to the cause. While treatment is empirical, clinical improvements over the years have made it highly effective.

Scoliosis usually, though not always, develops during the adolescent years, with the greatest progression during the time of the "growth spurt". When skeletal maturity is reached, the rate of progression of the curves decreases or stops, depending on the magnitude of the curve. Curves that measure over 40 to 50 degrees at or before maturity, usually progress during adult life, likely because of biomechanical instability caused by the severe angulation of the spine. Curves that remain less than 40 degrees at maturity, are almost always stable during adulthood. For this reason, the treatment selected depends on the severity of the curve.

Curves measuring more than 40 deg(approx) are usually fused to prevent the relentless progression seen during adult life for curves of this severity. The common techniques are the Harrington, Dwyer and Luque instrumentation and fusions. The Harrington procedure is carried out through a midline incision of the back, with the placement of a steel rod in the concavity of the curve, to distract the curve. The spine is then fused. The Dwyer procedure is an anterior approach to the spine, with clips placed around the vertebral bodies and a cable through the clips pulling the bodies into alignment. The Luque procedure uses the same approach to the spine as the Harrington, but uses sublaminar wires at each level to fix the bones of the spine to the rod. Post fusion treatment may involve braces, or casts for varying periods of time until the fusion mass is solid. In all these procedures, the curvature is significantly corrected (although not all the way) and when the fusion is solid, the curve should show no further progression.

In the case of smaller curves in a growing child, treatment usually involves long term bracing programs in an attempt to prevent the curve from progressing to the point where it is severe enough to require a surgical fusion. The usual mode of bracing has been the Milwaukee brace developed in the 1940's (3,4). Three vertical rods are attached to a tight fitting pelvic bucket at the bottom, and a neck ring at the top. Pressure pads are located between the back and front bars to provide pressure on the rib leading to the apex of the curve. The brace must be worn for 22 hours per day and the patient has a series of exercises that are done in conjunction with brace wearing. Properly worn, the brace appears to effective in treating these curves. However, non-compliance is the major problem with brace wearing; published studies often classify as many as 40% of the children as poor or non-compliant brace wearers. Among those who wear the brace as directed, psychological problems are common (5). Most of the patients are adolescents forming social relationships and 85% of the patients with the progressive form of the disease are females. The brace also tends to promote atrophy of the paraspinal muscles and loss of flexibility of the spine.

In response to the problems of brace wearers, much effort has recently gone into the development of low profile braces that are more acceptable to the patient and can be disguised under clothing. Several of these are currently available, for selected curve types and patterns (6).

ELECTRICAL STIMULATION

More than 12 years ago, work was started on the development of a system to use electrical stimulation of the paraspinal (back) muscles for the treatment of scoliosis in children (7,8). The work arose from the concept of Dr. W.P.

Bobechko,(Chief of Orthopedics, Hospital for Sick Children, Toronto), that stimulation of these muscles could produce a muscle imbalance that would alter the direction of growth of the spine. Animal experimentation carried out by the author showed that the use of unilateral stimulation would cause the spine to grow towards the stimulated side. Histological and histochemical studies were carried out to measure the changes in the muscles as a result of the stimulation. It was found that there was a conversion of the fibre type to a more fatigue resistant fibre as a result of the stimulation. No serious pathological changes were seen using the implantable systems with intramuscular electrode systems except for a small region of localized fibrosis around the implanted electrodes (9-11). With this background data, development was carried out on both an implantable system and a surface stimulator device. The system would apply stimulation on the convex side of the curve so the induced tendency of the spine to grow towards the stimulation would counter the deforming force of the scoliosis. The treatment was designed around night use only to minimize its affects on the patient's daily activity.

ELECTRO-SPINAL INSTRUMENTATION

The implantable stimulator system is called Electro-spinal Instrumentation (ESI),and is manufactured by Medtronic, Inc. Minneapolis Minn. It is a radio-frequency (RF) coupled device with a small implanted receiver unit and an external transmitter-antenna system. RF coupling was chosen because it allowed the alteration of the parameters of the stimulation after the system was implanted.

a)EQUIPMENT

(i)Receiver-Lead: The presence of both single and double curves necessitated the design of both single and dual channel units. The receiver is a flat disc (single channel unit: 24 g weight, 3.8 cm diam; dual channel unit: 45 g weight, 4.5 cm. diam) cast in epoxy and coated with silicone rubber. It has a receiving circuit tuned to the transmitter frequencies. For the single channel and channel 2 of the dual channel unit, the carrier frequency is 460 kHz. The carrier frequency of channel 1 of the dual unit is 185 kHz. The receiver integrates the RF signal, producing a train of stimulating pulses that are sent to the muscle by the leads. Until three years ago, the leads were platinum-iridium 'tinsel' wire (4 or 6 stranded) coated with silicone rubber (either extruded or molded). The present lead is a triple helical coil of a silver alloy wire coated in polyurethane. The leads terminate in small intramuscular corkscrew electrodes of platinum wire. Each channel has three leads attached to it, with the two negative electrodes in common, and a positive in the centre.

(ii)Transmitter-Antenna: The transmitter is a battery operated unit, the size of a small pocket radio. The output amplitude is adjustable to provide up to 12 volts into a 1 kohm load. The pulse width, pulse rate, on and off cycle times are also adjustable by screwdriver. The antenna is on the end of a 150 cm. long cord and is a flat disc 8 cm. in diameter (3 mm. thick). It is taped on the patients back at night with a double sided adhesive disc. Because the RF signal is transmitted through the skin, no conductive paste is needed. The transmitter is placed in the patient's bed at night. The stimulator cycles on 1.5 sec, off 9 sec, (pulse width 220 usec, at a rate of 33 pulses per sec).

b)INSERTION OF RECEIVER

The receiver is inserted under general anesthetic through a straight skin incision exposing the paraspinal muscles on the convex side of the curve. Trial needle electrodes are used to find the strongest contraction with the best acute straightening of the spine. Special inserting tools are used to insert the corkscrew electrodes into the position of the test needles. After the receiver is placed into a subcutaneous pouch, the skin is closed in layers using absorbable sutures. The patient is then discharged home within two days, and seen back as an outpatient 10 days later. At that time, the patient is instructed in the use of the device, initial level settings are made, and the patient sent home to begin nightly use.

c)FOLLOWUP

Followup visits are scheduled every 9 months. At each followup visit, the patient turns off the unit in the morning, and is seen as an outpatient in the afternoon. A standing AP X-ray is taken with the unit turned off (and having been off for 5 to 9 hours at that time). The output of the unit is tested and the stimulation assessed clinically. Any necessary amplitude changes are made and then the patient is sent home. At skeletal maturity, use of the device is terminated; yearly followups are instituted. Patients failing to respond to treatment receive a fusion to prevent further progression of their curves.

d)PATIENT SELECTION PROTOCOL

Patients were accepted if they were skeletally immature (Risser I or less) and had a curve greater than 25 deg, or in the case of a double curve, one of the curves was greater than 25 deg. Both single and double curves were accepted, and patients as young as 3 1/2 yr. were treated with an implant. As a general rule, we no longer accept curves over 45 deg for treatment, since they are unlikely to be stable during adult life.

e)RESULTS

There are 169 patients (79 single and 90 dual channel) and 259 curves under treatment with ESI for idiopathic scoliosis. The data consists of 146 thoracic, 73 thoraco-lumbar, and 40 lumbar curves. More than two-thirds of the curves are equal to or greater than 30 degrees at the start of treatment. The curves had been progressing at an average rate of 6 degrees per year before the start of treatment. At the start of treatment, the mean curve was 34 degrees; average followup is 2yr 4mo.

Over the course of treatment, the curves show an average improvement of about 20%. However, at the

end of treatment, the mean curve is the same as the starting curve, 34 degrees. In a subgroup of 79 curves followed to and beyond skeletal maturity, there is no further change in the mean curves measured at up to 3 years after the cessation of treatment at skeletal maturity. This group was treated for an average of 2yr, 11mo to maturity.

There were 28 (11%) curves that failed to respond to treatment and continued to progress, requiring Harrington instrumentation and fusion. This group showed more than 10 degrees of progression during the period of treatment.

There have been very few complications or problems encountered. The 6 strand, molded rubber tinsel wire used prior to the present lead set, had a failure rate of about 2%. The current lead (coil in polyurethane) has 250 sets in use for up to 2 1/2 yrs. with no failures. There have been no problems with the receivers. Compliance has been over 99%, and there are no problems with skin irritation, pain, or sleep disturbance.

ELECTRO-SPINAL ORTHOSIS

The potential use of surface stimulation for the treatment of scoliosis was investigated clinically from about 1976 on. Before that time, preliminary clinical trials by Dr. N. McCollough III, (Dept. Orthopedics, University of Miami) indicated that surface stimulation might be able to control the progression of scoliosis (12). However, the early studies were done on children with very small curves and later work has suggested that many small curves may not be progressive. To study the efficacy of surface stimulation, a multi-centred clinical trial was set up with a protocol requiring that the curves be a minimum of 25 degrees at the start of treatment, unless there was documented evidence of 5 deg of progression and that the patients be skeletally immature.

a)EQUIPMENT
The stimulators used in the study were single channel (model 3120, Medtronic, Inc, Minn) or dual channel units for double curves (model 3120-2, Medtronic, Inc, Minn). Both stimulators were battery powered units. The single channel unit produced a train of pulses at 50 pulses per sec, 425 usec wide, cycling on 5 sec, and off 25 sec.while the dual channel units had a pulse width of 225 usec, with a pulse rate of 35 pulses per sec. The single channel unit had a 0.5 sec ramp on while tha dual had a 1.5 sec ramp. Both units were a constant current design, and had a capacitively coupled output, with a maximum current of 50 mA. for the single channel units, and 100 mA. for the dual channel units. The skin electrodes were carbon filled silicone rubber (5 x 2.54 cm.) attached to the stimulator by a 120 cm. long cord. Conductive paste or karaya pads were used between the electrodes and the skin.

Treatment was carried out at night while the patient slept, with no daytime activity restrictions or bracing. Followup was at 4 month intervals with a standing AP X-ray taken with the stimulator turned off. In the case of all followups, the unit was off for a minimum period before the X-ray.

b)PROTOCOL
Patients were accepted in the study if they had a single or double scoliosis measuring between 25 and 40 degrees or less than 25 with a 5 deg history of progression. Patients and their parents were instructed in the use of the equipment and the proper electrode locations. Information as to the proper use of the unit, and the handling of any skin rash problems was given.The patient was sent home and seen at 1 week, 1 month, and then at 3 month intervals. Curves were followed by X-ray.

Electrode placement was classified as one of three possible locations. Paraspinal placement was with the pad adjacent to the spine on the convex side, with a separation between the electrodes of about 2 cm. min. The lateral position had the electrodes on the axillary line on the side of the body, again on the convex side. An intermediate position was also used, with thee electrodes about halfway between the other two postions. In all cases the electrodes were on the convex side of the curve and above and below the apical rib. The choice of the position for the particular patient is based on that which produces tha most straightening of the spine acutely. Assessment was either by palpation or by X-ray taken during contraction.

c)ASSESSMENT
The results were assessed by comparing the latest X-ray with the last X-ray taken before the start of treatment. If the change was 4 degrees or less either way, the result was listed as unchanged (UNCH). Corrections of 5 degrees or more were classed as improved (IMP), while progression of 5 degrees was progressed (PROG).

d)RESULTS
In this study, a total of 121 patients are presented as fitting the described protocol with adequate followup to assess even the early results. A further 115 are in this excluded group. In the analyzed group, the mean curve size at the start of treatment was 28 deg, with the largest number of patients in the 11 to 15 yr old age group. Thoracic curves made up 73% of the data, while there were 18% of thoraco-lumbar curves, and 9% lumbar. Eighty per cent of the patients had less than two years of followup, with a mean of about 1yr 4 mo.

In the study, 28% of the patients were classed as Progressed, 54% as Unchanged, and a further 18% with significant improvement in their curves. Table 1 lists the results of treatment stratified according to various starting criteria.

Table 1: Results of Treatment of Protocol Group.

	Impr	Unch	Prog
Curve Size			
20 - 29 deg	20	56	24
30 - 40 deg	16	51	33
Curve Location			
Thoracic	13	56	31
Thoraco-lumbar	26	48	26
Lumbar	36	55	9
Electrode Position			
Paraspinal	29	42	29
Intermediate	11	66	23
Lateral	14	56	30

The data indicates that the lesser curves do better than the more severe ones. The lumbar curves also do best, while the thoracic curves appear to be hardest to successfully treat. The paraspinal electrode position produces the best corrections of the curves, while the intermediate position has the best overall success for treatment. The lateral placement is the least successful by a small margin.

e)COMPLICATIONS

Problems arising from the use of surface stimulation are generally not too serious. The major problem is skin irritation, which is usually of a minor nature, and can often be kept under control by changing to different conductive pastes. Approximately 25% of the patients are troubled by some skin irritation, although the actual number who have to be discontinued for this problem, is only about 4%. Hypersensitvity of the skin has been reported in a couple of cases. Pain on stimulation and sleep disturbances are other frequent problems which require attention. The only major concern is the need to educate the parents and patient to place the electrodes in the correct position, since inappropriate positioning of the pads can leave the curve untreated, or even worsen a second curve.

DISCUSSION

Both the implantable and surface systems have been in use for nearly 10 yrs. In both cases, the success rate of treatment is similar, although the patient populations are not quite the same. The ESI group is younger on average, with a more serious curve and represents a higher risk patient. As a general rule, the ESI patients get more correction (those in the IMP group), with a better improvement in the rotation. There are no skin irritation problems in ESI since there is no paste in use, and there is no unpleasant sensation since skin nerve receptors do not respond to the RF signal. ESI antennas are placed by the children themselves, and do not need the parental involvement that ESO does. Misplaced electrode placement by parents is a continuing problem with ESO, often leading to loss of correction in the curve. In the ESI system, misplacing the antenna only leads to a decrease in the strength of the stimulation; what is present is still properly applied. The major drawback to the use of ESI is the need for the surgery with the general anesthetic and surgical scar. This is currently being investigated in an attempt to minimize it. Both modes of treatment using electrical stimulation are proving themselves to be effective replacements for the troublesome bracing programs. They are finding excellent patient and surgeon acceptance.

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THE SEARCH FOR ALTERNATIVES

Harold H. Wilke, STM., DD.
Healing Community, White Plains, U.S.A.

ABSTRACT - Alternatives to institutional care and to the use of prostheses are discussed using my personal experience as a bilateral upper-limb amputee.

RÉSUMÉ - On discute des solutions de rechange aux soins en établissement et aux prothèses à partir de mon expérience personnelle comme amputé des membres supérieurs.

"Send this child away to a rehabilitation institution, for training and education, and I will pay for the bill". This generous word came to my parents when the time for my schooling had come.

The words must have been tempting indeed. Surely, how would it be possible for a child with total upper-arm limblessness to be able to make his way in the world without a replacement for those lost arms, and training in the use of them? Surely this child could not develop his potential if he were kept without arms. Surely this youngster would need to look as normal as possible in order to fulfill any relationships at all in the world. Surely he would need the trained eye of a rehabilitation expert, guiding him on the way to independence to the extent possible in daily living activities. Surely a formally uneducated set of parents would not have the right answers for a child as severely handicapped as this.

All the "surelys" weighed heavily on my parents. They were certainly most tempting. The cogency of the argument must have been very real to them, and its logic irrefutable.

They were not stupid people. Father had served on the Library Board of our town, and was indeed a descendent of that Rousseauan tradition in Europe of finding a place on the land, returning from the false sophistication and learnings of academic and city life, to the soil. Their forebears had participated in the so-called "Latin farmer" movement. Moreover, they were stong-minded people.

My parents therefore studied what tney saw as two options:

1. Institutional care away from home.

2. Care at home, recognized to be non-professional.

They considered the options in turn. Under that of institutional care, they considered the following questions and problems:

a) How could they say "no" to such a gentlemanly offer as their deeply concerned and generous friend had made to them? That thoughtful offer had crystallized and then made possible what most people in the community thought of as the only alternative.

b) But could the technology of that time - 1920 -provide an adequate mechanical substitute for an arm? There was at that time nothing of the sophistication found in prosthetic devices today.

c) If utility could not be achieved by mechanical means, was cosmesis necessary? Was it required that one "look normal"? Could society accept a person who was so obviously different from others? And could this child accept a body image that was so obviously different from that of everyone else? My parents vividly saw how this child had become so widely independent, so able to take care of so many of his needs, so open to alternative thinking, so able to fulfill, with variations, routine work in which parents and other children engaged around the house and barn and field. Extrapolating from that, they could surely sense that still other alternatives could be found and would develop as time went on.

d) They also recognized that their own deep feeling that sending a child away from home carried many difficulties, that in it lurked perils, that institutional care was a very unknown quantity in terms of the development of human relationships.

They considered also the second option of that of remaining ar home:

a) What would people say? How could they deal with a community attitude that recognized science, rehabilitation, and doing what the professionals said, as the right answer, and that keeping the child at home was a kind of defiance of authority?

b) Could they be sure of their own ability to care for and train this child? They were successfully caring for one normal child already, and surely this one would not be all that different?

c) Would their affirmation of the indomitable human spirit be sufficient? Would this child's already demonstrated ability to care in so many ways for himself develop even further? Would a plateau or chasm be reached beyond which further growth would not be possible?

d) Is the loving and sustaining care within a home, the growth of deeply and positively significant relationships, which of course they felt was part of their family, be sufficient in helping this child if he did not have the other?

e) Was a positive decision not to keep their child at home an answer to a deeply tempting possibility, that of washing their hands of the whole situation? How simple, psychologically and emotionally, would it be to turn the problem over to other people and get on with the business of living?

Their decision was made, or perhaps just allowed to happen. And I stayed at home, not leaving until time to go away for college and university study.

Alternative methods for self-care were therefore probably spurred by this decision. But other methods were also brought into being by the simple fact of a busy household requiring me to do as many things as possible on my own, and to find those methods by myself. My mother was busy. There was another child in the home to care for, whose squalling required far more attention than my more inchoate needs.

The bumps inevitably suffered as an infant learning in the usual kerplunk method peculiar to babies as they master balance and locomotion and finally walking were painful, I'm sure, when my top half - the centre of gravity - got too far abead of my base of support, (I could not catch myself with fat little hands and arms - as I later would watch each of my five sons do. I landed on my collar bone, my head, my nose, whichever touched down first. The broken profile of my Roman nose attest to a break in one such fall!)

My continuing pain, out of my experience, is that of facing the fact of my difference - and the even harder fact that many of those "normal" folk around could not either face or accept my difference. This fact is still a daily component of my life - but most days the frustrations I face are not those of judgement of my fellows - not even the frustration a physical world set up - and sometimes poorly at that - for persons with the usual component number of appendages, but instead, that occasional rejection because of a difference seen as pejorative and negative.

The very title of our paper "The Search for Alternatives" suggests that learnings come out of seeking alternatives, in searching for new ways. After the immediate difficulty of seeing the closed door, the next step is finding a window or a trap-door. It is seeking new alternatives and new outlets.

Such alternative-seeking happened to my father and also to me. The one for my father came when I was excluded from school. The superintendent of the public school system said to my father "Your son is not acceptable in the city school system". This was a shock to my father, who as I mentioned earlier came out of thay Rousseauan tradition in Europe through my great grandfather. Thus my father, his gandson, was one who held that intellectual life of tremendous importance. For this youngster of his, then, to be denied schooling was searing. What he had to do therefore in finding a way out of his pain, out of an almost numbing shock, was to find alternatives. At that point he found the one-room country school house which I attended for numbers of years. The pain endured for him. It was there in part because the schoolboard had simply held to the adament stance of the first grade teacher, who stated: "No, we cannot accept this child. In all the fifty years I have been teaching here I have never had anyone like this who writes with his toes and I'm sure all the other scholars will be watching him all the time and therefore will pay no attention

to their own lessons". (She certainly has learned little about the attention span of children during her fifty years of teaching!) That denial of education was felt even more deeply by my father partly because the response had a "circus act" atmosphere about it.

For me the alternative school was a great experience. I didn't know the complexities of what was happening, or what lay ahead for me. What did was the fact thay I could attend the one-room country school house with all its special joys. For numbers of years I walked through two forests on the three-mile trek to school, across several streams, cutting through the pasture where the neighbour kept his bull (so that at least several times a year we had to run for it to escape the enraged animal). The very way I mention this shows how much I enjoyed the whole experience. I don't know how much I enjoyed my studies but I sure did enjoy going to and coming from school!

Some years later the rejection pain hit me. I applied to a college and was told "We cannot have a crippled kid on campus". The fact that within the week I received an acceptance from Princeton may have alleviated the pain level for me somewhat. But the fact of rejection, the knowledge of the reason for the rejection, occasioned real pain. I know full well I overcame the pain, not by with-drawing, not by taking this denial "on the chin", but by bouncing back. I affirmed my own identity. I knew who I was and what my identity was. All of this I owe tremendously to parental and sibling response to me. It helped create a sense of identity to me, so that nobody, not even the president of some college or other, could beat me down, because I knew who I was, and indeed -- from my church relationship -- Whose I was.

Rejection, then, has an element in it which calls upon the resilience of the human spirit. The rejection somehow calls upon us to affirm once again the identity which is ours.

But there are rejections which have nothing to do with whether we are accepted in school but rather have to do with something at deep levels of intimacy, of what is proper, of what is esthetic. Such pain came to me when I attended the junior - senior prom. The high school gymnasium was filled with vari-coloured streamers - lovely indeed! It was a nice party; good singing and talk and all, and then we were sitting at card tables eating ice cream and cake. I eat ice cream - everything, in fact, by holding my fork or spoon in my toes. At that point I still wore socks on which the front inch was cut off so I could have some protection against a mid-Western winter and at the same time be able to handle the pen and pencil and so on in school. That's the way I arrived that night - all my five little piggies stuck out! Get the picture: there I was one of the juniors, another junior off to my right, a lordly senior across from me and our history teacher on one side. I thought Miss Wyatt looked at those bare toes with repugnance. I felt that she was, in effect, saying to herself, "Bare toes don't belong on the table, in fact feet don't belong on the table!" For months I had studied in her class with my foot on my desk, just as others had their hands on their desks, taking notes. But a party - a festive occasion - was different; she was unable to translate my action in school classroom to the "dining room". I felt real pain that night. I thought that I was being looked down upon. I felt I was seen as boorish. At home after the prom that night I said "Mom, we have got to change this. What can we do? How can we fix these socks so that on the one hand I can be comfortable in snow and on the other hand I can still have toes free to write?" That night my mother and I invented the tabi sock. (We didn't know that the Japanese had invented it a thousand years ago, so we invented it that night for ourselves). The mitten sock we created covered the toes, yet provided opportunity to grasp pen and paper. Again, it was a matter of finding alternatives; the pain was overcome in finding new ways. In some ways of course, the pain was twisted but it found a real expression in a new outreach so that the pain was in fact redeemed for me in finding this particular alternative. Alternatives do not reduce the level of pain, but set it in a meaningful context.

That Zipper Incident

From early on I strove for independence in daily living activities. One incident in this concern for new or alternative ways of caring for myself was at age twelve, in my first encounter with zippers. I wrote to the people who invented them: my letter in around the year 1926 was beautifully written (my foot-writing was much more legible then than now) and stated:
"It occurs to me that your Talon fastener would work very well for me in my own dressing process if they were secured to a pair of trousers. If I sent you a pair of my trousers, would you put zippers on them for me?"

Their answer intrigued me then and intrigues me still: "We have never heard of anything like what you propose, but will try. If you send us your trousers we will attempt to put zippers on them".

Universal Applications of Principles

The principle of coping, of "using everything you've got", of the constant search for alternative methods, of the use of the third eye, of imagination and another stance, is of course universal in rehabilitation engineering. It is applicable to all persons, even at various ages, and whether traumatic or congenital.

For example, of persons with whom I have worked intensively in daily living activities, one had a traumatic electric burn with total loss of both arms at the age of thirty. On my third visit with him over the course of two years he was holding fork, spoon and glass in his foot at the table - still a low coffee table - and was driving his own car over the hills of Seattle with the same method I taught him. A woman, over thirty, with traumatic loss of both arms, developed foot-use over the course of a year, although she continues to use one prosthesis on the arm where an above elbow stump was maintained. Activities requiring special handling - toileting, dressing and cooking - are done with her toes.

It is all engineering! When I carry that log to the fireplace, balanced on my foot, when I reach up for that public telephone in Grand Central Station or elsewhere, when I sway and balance my body properly in early tightrope walking and when I flex my body to hand the dollar bill to the toll keeper on the turnpike with my foot way out the window (or when I drive for long periods with my foot on the steering wheel) - all of this is applied engineering.

I symbolize therefore <u>another aspect -- another orientation of your rehabilitation engineering</u>.

Looking with the third eye is a concept which grows out of coping. It is the imaginative use of materials or processes in such a way that the same end result is achieved even though the standard operating procedure was not followed. Again, to be personal: to you, a coat is something you put on and button; for me, a coat is something that I button and then put on. With the third eye, we imaginatively look at the desired result and seek alternative ways of fulfilling it. While this is true of the individual personally at the physical level, it is obviously true also at varied levels for the human, and indeed for organizational processes as well.

The utilization of all resources is a concept in which one quite intentionally and systematically seeks out all possible resources.

Religious faith, the sense of being in a loving community, the assurance of a parental group, the love of a spouse - all of these are resources I have touched upon. They suggest the unlimited range of possibilities in the inner resources of the individual.

These and other principles of resourcefulness are part of the psychological engineering with which a person with a disability responds both to that disability and to society. These principles must become an accepted part of the armamentarium of rehabilitation. Obviously, most of these are constantly in use by the professional as she or he works with the patient. My call now is for these principles to be lifted from a casual or perhaps even unconscious base in personal work with a patient, lifted to an understanding that makes their use unintentional in nature, and discrete in character. As professionals, we need to become intentional in the use of these principles, and make them a kind of counterpart to the technological aspects of our profession.

PROGRESS ON THE PREVENTION OF AMPUTATION THROUGH VASCULAR SURGERY

Paul M. Walker, M.D., F.R.C.S.(C), Assistant Professor of Surgery
Toronto General Hospital, University of Toronto, 101 College St., M5G 1L7

ABSTRACT - Vascular insufficiency remains the most common cause for lower extremity amputation. There has been progress in the prevention of these dysvascular amputations, including better identification of patients at risk, and increasing the distal blood flow by both improved surgical procedures as well as nonoperative methods. However the ability to either successfully arrest the process of atherosclerosis or reduce its incidence by risk factor control remains challenging.

RÉSUMÉ - L'insuffisance vasculaire demeure la cause la plus fréquente de l'amputation des membres inférieurs. On a fait des progrès dans la prévention de ce type d'amputation par un meilleur dépistage des sujets à risque, et par un accroissement du débit sanguin distal grâce à des méthodes chirurgicales et non chirurgicales améliorées. Toutefois, enrayer la progression de l'athérosclérose ou réduire son incidence en agissant sur les facteurs de risque demeurent un défit.

Peripheral vascular occlusive disease (PVOD) reduces the blood flow to the tissues of the lower extremity. There is narrowing of the intraluminal diameter of the affected arteries, because of a laying down of plaques composed of a complex combination of thickening of the muscle wall, lipid infiltration, calcium and cholesterol depositions. When the blood flow becomes severely restricted, ischemic gangrene occurs and amputation is inevitable.

Progress in the prevention of dysvascular amputations has been made on several fronts, including 1) a better understanding of the natural history of PVOD, 2) improved diagnostic techniques, 3) improved surgical techniques for arterial reconstruction and 4) improved nonoperative methods for increasing distal blood flow.

THE NATURAL HISTORY OF PVOD

Mild narrowing of the blood vessels supplying the lower extremities first causes the symptom of intermittent claudication. The blood flow is sufficient at rest but during exercise blood flow to the exercising muscle is inadequate and muscle pain with cessation of exercise results. With a progressive increase in the severity of the narrowing, there is not enough blood flow to maintain normal metabolism even at rest and the symptom of night or rest pain is present. This pain is predominantly located in the forefoot or toes and is caused by ischemia of distal skin, bone and nerves. With even more progression of the narrowing or a wider distribution usually involving two different segments, gangrenous changes occur in the skin of the lower extremity. Blood flow is reduced to only a fraction of the usual amount.

Over the course of the last 15 years a better understanding of the natural history of each of these separate symptoms has become evident. Initially a large volume of vascular reconstruction was performed on patients with the symptom of intermittent claudication, since progression to amputation was considered inevitable. Professor Boyd of Manchester first reported a benign prognosis for stable intermittent claudication (1). He found that the amputation rate in patients with PVOD, and stable intermittent claudication as their only symptom was 1-2% per year. In fact, while most patients with PVOD remained unchanged a significant portion of them improved, and only a very small percentage either required reconstructive vascular surgery because of progression of symptoms or in fact went on to amputation. Thus needless reconstructive surgery for intermittent claudication has been reduced dramatically, and concommitantly a reduced incidence of amputations because of acute failures of vascular reconstruction. In a recent publication we were able to show that in patients with acute superficial femoral artery thrombosis when limb viability was not threatened, an improvement in symptoms with time is most likely (2). We were able to show an increase in walking distance from a mean of 50-60 feet to 5 blocks over the course of 18 months. An alteration in skeletal muscle metabolism with improved aerobic capacity has been identified in patients with PVOD, and this may help explain their increased performance despite a reduced blood supply (3).

While the benign nature of stable intermittent claudication has been more fully understood the importance of night and rest pain has also been more understood. The prognosis for those patients with night or rest pain or gangrenous distal changes remains grim if left untreated. Most of these patients will progress to amputation, unless an increase in distal blood flow occurs. To prevent amputation it is therefore important to identify this subgroup of patients with PVOD, and these symptoms and somehow increase their lower extremity blood flow.

DIAGNOSIS OF PVOD

Progress in prevention of amputation has been made by improvements in diagnostic techniques. Noninvasive investigations of PVOD has significantly improved out ability to uncover vascular causes of impending amputation. Measuring the systolic blood pressure at the ankle using Doppler ultrasound techniques and comparing it to the systolic blood pressure at the wrist is a simple yet highly reproducible method for identifying patients with PVOD. In most cases the ankle/arm pressure ratio is greater than 1.0. The resting ankle/arm pressure ratio not only identifies the presence or absence of occlusive vascular disease in most patients, but as well is able to quantify the severity of narrowing present. Ankle/arm systolic pressure ratio of .4 to .6 is compatible with stable intermittent claudication while below that level, the incidence of night or rest pain or distal ischemic changes becomes great.

Analysis of the Doppler waveform obtained from the femoral, popliteal, dorsalis pedis and posterior tibial arteries can be evaluated either visually or using various methods of frequency analysis. From this information localization of vascular occlusive disease has become possible.

VASCULAR RECONSTRUCTION

The best method for increasing distal blood flow and thus preventing amputation lies with successful vascular reconstructive surgery.

In order to determine whether a bypass procedure is in fact possible, visualization of the arterial tree is required. A direct arterial injection of radio-opaque dye, with multiple exposures, usually leads to a good identification of areas of narrowing as well as the nature of the vessels beyond the block. Newer techniques to fully visualize the arterial tree including intravenous injections with computerized enhanced subtraction studies, which do away with the risk, albeit small, associated with an intra-arterial dye injection.

The surgical management of limb threatening peripheral vascular occlusive ischemia is dependent upon being able to remove or bypass the major obstruction but also requires the presence of an adequate runoff or outflow, beyond the resistance removed, to ensure a rapid enough flow of blood to prevent insitu thrombosis.

An improvement in the patency of these reconstructions and consequent prevention of amputation has been associated with a change from just cleaning out a segment of the occluded artery to bypassing from above the area of narrowing to below it, using either autologus tissues such as saphenous vein or prosthetic material (4). The techniques of revascularization and results are divided up according to the anatomical location of the predominant narrowing present.

Revascularization of limb threatening aortoiliac occlusive disease has a high rate of success related to the large size of arteries involved and the durability of Dacron as a prosthetic conduit. Patency rate and limb salvage rate of 90% at five years and 80% at ten years of followup can be achieved (5). An improvement in the limb salvage rate has been associated with extending the bypass graft to the level of the common or profunda femoris artery.

Surgical management of infra-inguinal occlusive disease causing limb threatening tissue loss remains more challenging because of the small nature of blood vessels present both in the inflow as well as for outflow. Reconstruction of this area may be hampered by the lack of a suitable long saphenous vein, which is the ideal conduit. If it is absent then prosthetic material must be used and unlike the aortoiliac segment, in this region prosthetic material is not as good as autologus tissue.

Greater ingenuity must be used in order to adequately reconstruct the arteries of the lower extremities. Specifically further advances in lower extremity revascularization have included the use of graft to isolated tibial arteries, sequential grafts in which more than 1 artery is used as an outflow and finally, insitu vein grafts. The overall patency rate and thus prevention of amputation is dependent upon the localization of the narrowing, the degree of ischemic change present and finally the degree of runoff (6). The average patency rate varies from between 30 and 75% in 3-5 years of followup. However, life expectancy in this group of patients is significantly reduced with only 50% of patients alive after 5 years usually due to cardiac death. Therefore, prevention of an imminant amputation for dysvascular causes may allow a patient with widespread atherosclerosis to preserve his extremity, but progression of disease may still result.

Surgical revascularization has thus significantly reduced the rate of amputation, but especially in the infra-inguinal area, remains imperfect.

NONOPERATIVE IMPROVEMENTS IN DISTAL BLOOD FLOW

Newer techniques of nonoperative management of peripheral vascular occlusive disease causing limb threatening ischemia includes transluminal dilatation, sympathectomy and pharmacological preparations.

Transluminal angioplasty, originally described by Grunzig, involves a balloon catheter, inserted under local anesthesia into the affected artery, and forcefully dilated. This ruptures the plaque which is present and increases the lumen of the affected artery. Experience with over 800 TLD's

has indicated that the more proximal and the shorter the length of the narrowing that exists the greater the chances of success. The degree of increase in distal blood flow seems to be less than arterial reconstruction and the duration of the effect shortened. This particular technique seems to be most useful in patients with intermittent claudication for when threatened tissue loss occurs often more than one arterial segment is involved, and the artery is narrowed over a long distance. However, the complication rate with TLD is low, and if the patient is too sick to undergo reconstructive surgery, this technique has certainly prevented amputations (7).

The sympathetic nervous system acts as a vasoconstrictor of the arteries of the peripheral circulation. In fact division of the sympathetic nervous system supplying distal arteries, called a sympathectomy, was the original vascular procedure performed. While it fell into temporary dysfavour during the early periods of arterial reconstruction, it has re-emerged, perhaps in a truer light, as a useful method for increasing distal blood flow. In a prospective study (8) we are able to evaluate quite clearly the usefulness of a sympathectomy in increasing distal blood flow. A small increase in distal blood flow associated with a sympathectomy could not be expected to reverse large areas of threatened tissue loss. If an autosympathectomy has already occurred, due to the degenerating effects of diabetes on the distal nervous system, then division of the sympathetic nervous system will not cause a further increase in distal blood flow. If the ankle systolic blood pressure is low, an anaerobic glycolysis is present and the metabolic waste products are a potent vasodilator. Again a sympathectomy is not likely to be additive. However in patients with small areas of distal gangrene, or night and rest pain, with ankle pressures greater than .35, a sympathectomy is successful in preventing the inevitable amputation. The operative morbidity and mortality of sympathetic division is high, related to concommitant disease. We use a direct injection of phenol into the L2 and L4 sympathetic ganglia, as a method of sympatholysis and feel that the results approach those of surgical removal, and are associated with little or no morbidity (9).

Pharmacological vasodilation has proved to be a rather unsuccessful method for increasing distal blood flow. As in the case of sympathectomy, local vasodilation in the affected extremity exists because of local products of metabolism and systemic vasodilation is not likely to increase distal blood flow. The most recent vasodilator being studied belongs to the prostaglandin group and that is prostacyclin or PGI2. A randomized prospective study of PGI2 in the management of patients with PVOD is underway. It is a natural product of healthy endothelium and is not produced by endothelium affected by atherosclerosis. PGI2 causes both significant vasodilation as well as interfering with platelet aggregation. The initial results are mildly encouraging, but further work is needed in order to define the place for this method of increasing distal blood flow enough to maintain tissue viability.

Inconclusion there have been significant advances in the prevention of dysvascular amputations. An improved ability to identify patients with remedial vascular causes of threatened amputation and more aggressive surgical management, with inventive efforts at direct vascular reconstruction have had the most positive effects. Currently, technical problems include perfecting a small prosthetic conduit with appropriately matched compliance and low thrombogenicity still exist. Management of the risk factors of vascular occlusive disease remains challenging and until there is progress made in reducing the damaging effects of smoking or diabetes for example there are likely to still be many patients requiring the many and varied aspects of post amputation management.

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THE BIOMECHANICS OF ORTHOTICS

D.N. Condie
Tayside Rehabilitation Engineering Services, 133 Queen Street, Broughty Ferry, Dundee

ABSTRACT - Orthoses are employed to achieve a wide range of clinical objectives. In each case the orthosis achieves its function by the application of a system of forces which modify the forces and moments transmitted to the body structures in a particular manner.

RÉSUMÉ - On utilise les orthoses pour atteindre un grand nombre d'objectifs cliniques. Dans chaque cas l'orthose remplit sa fonction par l'application d'un système de forces qui modifient les forces et les moments transmis aux structures du corps, de façon bien définie.

ORTHOTIC FUNCTION

Normal physical activity is a complex phenomenon which requires the integration of the functions of the musculo-skeletal, neurological and cardio-pulmonary systems.

In many pathological situations one or more of these essential systems is impaired, leading to a functional limitation. In these circumstances orthoses are commonly applied to compensate or substitute for the impaired system to enable a more normal or alternate mode of function.

Irrespective of the required function most orthoses achieve their objective by virtue of the force system which is generated at the patient/device interface when the defined patient activity takes place. This force system is in turn a direct result of the mechanical characteristics of the orthotic system and the manner of its attachment to the patient.

ORTHOTIC FORCE SYSTEMS

The effect of the force system which an orthosis is responsible for generating is to modify the total force system acting on the body and on particular structures. It is possible therefore to summarise the choice of "orthotic functions" as either -

a) To modify the moments acting on a joint or segment.

b) To modify the forces acting on a joint or segment.

Consider the type of force systems which have been employed to achieve these objectives.

Moments

The most common force system employed in orthotics to produce an external moment is the simple "three force system". Applied across a joint or body segment this system of forces will produce its maximal modifying effect on the moment applied to the body at the level of the middle force (the fulcrum). The magnitude of the individual forces in the system necessary to generate a particular moment is inversely proportional to their distance from the fulcrum.

This simple mechanical observation suggests that in orthotic design it is important to utilise the maximum "lever arms" available. This is usually dictated by the length of the body segments enclosed by the orthosis.

A frequently employed variant of the "three force system" is the "four force system" or "double couple" which may be used where it is not convenient to employ a single middle force. In this case it is desirable to achieve the largest possible separation between the components of each couple in order to minimise the magnitude of the individual forces.

The "double couple" is always employed when it is intended to modify the moment occurring in the coronal plane.

"Three force systems" may be superimposed when it is desirable to influence two or more adjacent joints or segments thereby simplifying the design of the orthotic system.

Control of the moments applied to the body structure may also be achieved by applying "all round pressure" to the involved segments by the application of a close fitting cylinder.

The theoretical basis for this method of force application is the assumption that the soft tissue surrounding the long bones will behave as a fluid and that the resulting "hydrostatic" pressure will act to resist moments being applied to the skeleton. This approach has most commonly been applied in the acute management of fractures and in some cases of delayed or non union.

Forces

The form of modification of force on the structure most frequently requested relates to the force acting along the axis of a bony segment. Typically this requirement is necessitated because of discomfort due to damage to the skeletal structure whether by disease or trauma.

The precise distribution of the required force

system will depend on the level of force relief; however, the general principle adopted has been to devise a suitable axial support area proximal to the damaged site. Thus when relief is required below the level of the knee joint a "patellar tendon bearing" form of support has been adopted and when relief is required in the knee or at femoral level an "ischial tuber bearing" form of support is utilised.

When it is intended to modify the forces which act normal to the axis of the skeleton, the so-called "shear forces", two methods may be employed.

It is theoretically possible to define a "four force system" which applied to a joint or segment will provide total relief of shear in the zone which lies between the two central forces.

Simple rules apply to the positioning of these forces for optimum design. In this case the outside two forces should be positioned as far apart as possible and the central two forces should be placed as close as possible to the required zone of zero shear.

It is important to note that this force system will not modify the moments in the defined area of the structure.

The alternative approach to the problem of shear relief is to employ the "hydrostatic" approach already described. The same theoretical considerations used to support this type of approach to controlling moments on a segment may be employed to propose a mechanism for the relief of shear forces.

Obviously this approach is not specific and will theoretically provide simultaneous relief of both bending moments and shear forces. Also the hydrostatic principle cannot be applied to control shear forces across a joint.

In clinical practise it is frequently necessary for an orthosis to be applied which will simultaneously fulfil more than one of the objectives already discussed. Often the required design can be evolved by simply adding together the individual force systems required to achieve each objective.

Thus in the management of a painful degenerative condition of the ankle it would be possible to combine the three force system necessary to resist the ankle dorsiflexion moment with the proximal support necessary to provide axial force relief.

On other occasions the force systems required to achieve two separate objectives will interact and the combined objectives can only be achieved by the application of a third unique force system.

This may be demonstrated by looking at the force system necessary to provide both control of the flexing moment and the posterior shear force in the knee joint. In this case the three force system described for moment control and the four system for shear force control require to be replaced by a single different four force system.

Now that the basic principles of the design of the force system have been illustrated it is possible to pass on to the design of the elements of the orthosis which will be responsible for generating the required forces - the orthotic components.

COMPONENTS OF AN ORTHOSIS

It is possible to classify the individual components of an orthosis rather simply by reference to the particular role which they separately fulfil in achieving the required objective.

Three types of components may be identified -

a) Interface components

b) Joints

c) Structural components

The essential function of each of these categories and the resulting design characteristics may be defined.

Interface Components

As the title clearly indicates, interface components are the means of contact between the patient and the device. They transmit the controlling force system to the body structure. Several considerations have already been identified relating to the position of the forces, however further considerations may now be defined relating to the design of the component itself.

In order to achieve minimum pressure at the interface the force should be distributed over as large an area as possible.

When a force is applied to the body surface the tissues on the contact area will be displaced. If the orthosis is to function efficiently the interface components must be shaped and aligned to anticipate the tissue displacement under the planned loading pattern.

Obviously interfaces must be constructed of a material which is capable of withstanding the applied forces without damage. The material should be inert, odourless, lightweight, easily shaped, inexpensive and preferably cosmetically acceptable.

In the past metal components covered in leather have been employed; however, more recently, plastic laminates and moulded thermoplastics have been widely adopted.

Joints

Artificial joints must be incorporated in any orthosis which encompasses an anatomical joint when it is intended that joint motion should occur during the use of the orthosis. The design of the joint will dictate the type of motion which will be possible at the anatomical joint.

The currently available range of orthotic components offer four basic options -

a) To permit free action at the associated anatomical joint in one plane but to modify in some manner the motion possible in another plane(s).

b) To limit the range of motion permissible.

c) To resist or assist motion in a particular direction.

d) To prevent any motion occurring.

The type of control exerted by a particular joint is governed by its design and may readily be established by simple tests.

It is possible to represent the "control characteristic" of a joint graphically by plotting the resistance to motion exerted by the joint against the appropriate joint angle.

Most traditional designs of orthotic joints are of uniaxial construction while the anatomical joints which they are intended to control have a polycentric action. In these cases it is important to position the orthotic joint accurately in the best possible compromise position to reduce "pistoning" at the interfaces.

More recently several designs of polycentric joints have been introduced while many of the moulded plastic orthoses have no discrete joints and hence avoid this difficulty.

Structural Components

The role of these components is to link the interface components to one another and in the case of jointed orthoses to the joints.

To achieve this function efficiently, the structural components should be rigid and preferably lightweight. For ease of assembly and for cosmetic considerations the structural components should be fabricated from a material which may readily be shaped to conform to the shape of the enclosed body segments.

In the past structural elements have been fabricated from standard metal stock with an appropriate cross-section, and in recent years developers have experimented with pre-impregnated laminates which may be cured after ıaping.

many modern orthoses it may be impossible to stinguish the structural element from the joint ıd interface components. For example, in a oulded ankle-foot orthosis the three types of ɔmponent are integrated. In this case the joint ɔntrol characteristic is determined by the eflection properties of the posterior member of ıe orthosis while the interface components are ne cuff and footpiece sections. The structural .omponents are in effect the interconnections ɔetween these portions of the orthosis.

CATEGORIES OF ORTHOSES

The simplest classification of orthoses is the system of descriptors proposed by the Committee on Prosthetic Research and Development which consists of a series of "mnemonics" derived from the intial letters of the joint and body segments which an orthosis encompasses. Thus an orthosis which extends from the toes to the mid-calf region is described as an ankle foot orthosis or AFO.

This system of classification has received widespread international acceptance and has been proposed by the International Standards Organization as standard terminology.

Several other methods may be employed to classify orthoses by reference to their method of action.

Static/Dynamic

The concept of static and dynamic orthoses is frequently referred to in the literature; however the precise meaning of these terms has not been satisfactorily defined.

It is proposed that the term static should be applied to those orthoses whose control characteristic remains constant at all times and under all possible circumstances.

In contrast, the term dynamic should only be applied to those orthoses whose control characteristic varies as a function of some external factor.

An example of a static orthosis is the conventional lower limb orthosis used to control an unstable valgus position of the knee. The construction of this orthosis may be analysed as comprising -

a) Interface components, created by the thigh band, the knee strap and at the attachment to the shoe.

b) A knee joint, which is maintained locked during standing and walking and only released to permit the user to sit.

c) Structural components of steel linking the knee joint to the thigh band above and the ankle joint below.

This type of orthosis will apply a three force system to the knee joint which will maintain the joint in a corrected attitude and relieve the medio-lateral bending moment acting upon the joint. The function of the orthosis remains constant irrespective of the status of the limb and the nature of the external loading.

A more recently produced orthosis designed to treat the same type of condition is the Telescopic Varus/Valgus Support (TVS) which is a development of the earlier CARS-UBC Brace developed in Vancouver. This device consists of

a) Moulded plastic thigh and calf interface components and a leather knee strap.

b) A telescopic member attached by swivel joints between the thigh and calf components.

The knee strap is also attached to the telescopic member which thus acts both as an orthotic knee joint and as the structural link between the interface components.

This orthosis will also function to provide the three force system necessary to satisfy the clinical situation.

In contrast to the conventional orthosis however this orthosis permits normal motion of the knee joint by virtue of the action of the telescopic member.

Furthermore, the placement of the attachment straps for the knee strap determines that the controlling force system is only fully developed when the orthosis reaches full extension, which

alignment corresponds to standing upright or to the weight bearing phase of the walking cycle. It may be said that the controlling characteristic of this orthosis is dynamically varying as a function of the knee angle.

This feature of the design of the orthosis which results in the corrective moment being developed under precisely these conditions when the knee joint specifically requires protection is an excellent example of successful dynamic matching.

Static orthoses are often employed in the upper extremity in conditions of muscle weakness or loss of control to place the hand in a functional position. Most modern orthoses of this type are manufactured from a thermoplastic material. The functional elements of this orthosis are integrated in the one-piece plastic construction and the controlling characteristics are constant and unaffected by external factors.

More complex designs of orthoses are also employed to facilitate the rehabilitation of patients who have suffered an injury to the nerves or tendons providing hand and finger movement. These dynamic orthoses consist of -

a) Moulded plastic wrist and hand components and leather finger loops.

b) Spring steel elements which function both as structural members to link the interfaces but also as joints whose controlling characteristic varies as a function of the enclosed joint angle.

This orthosis will apply a system of super-imposed three force systems which resist flexion and assist extension at the wrist, metacarpo-phalangeal and interphalangeal joints thus stretching the contracted joints and providing immediate improvements in hand function.

When one considers the form of the characteristic created by this form of dynamic device it is apparent that the matching is in this case less accurate.

While the use of the simple spring elements dictates that the resisting moment will increase with increased joint flexion, it is possible to demonstrate experimentally that the slope of the controlling characteristic should preferably be reversed describing a system where the resisting moment increases as the joint moves into greater extension.

A dynamic orthosis incorporating joint elements with such a characteristic would still offer assistance to hand function but would in addition provide a more effective means of reducing joint contractures.

Direct and Indirect Functions

All of the orthotic principles discussed so far relate to orthoses whose major function is achieved by the direct action of the orthosis on the body segments and joints which it encompasses. There are however a few existing orthotic systems which act indirectly in a significant manner to modify the forces and moments acting on segments and joints which are not encompassed by the orthosis.

This distinction between orthoses which act in a direct or an indirect manner may be illustrated by examining the function of two simple ankle-foot orthoses.

The Ortholen Posterior Leaf Spring Orthosis (PLS) is a one-piece moulded thermoplastic orthosis. The constituent components may be considered as comprising a rigid calf section, a flexible posterior upright and a rigid footpiece. The control characteristics of the orthosis are a function of the flexible section of the posterior upright and the three force system which the orthosis imposes on the user posteriorly on the calf, anteriorly at the level of the ankle (by virtue of the shoe upper) and on the plantar surface of the foot.

This orthosis is normally employed for patients with specific weakness of the dorsiflexor muscles. It has a dynamic action arising from the elastic property of the high density polyethylene used in its construction and it acts directly upon the ankle joint to resist uncontrolled plantarflexion of the foot at heel contact and to assist dorsi-flexion of the foot after toe off.

The Polypropylene Solid Ankle-Foot Orthosis (SAFO) consists of a rigid shell extending posteriorly from the calf to the toes.

The control characteristic of the orthosis is a function of the rigid structure of the orthosis and the three force system it imposes on the wearer posteriorly on the calf, anteriorly at the level of the ankle and on the plantar surface of the foot.

This type of orthosis has been used extensively in Dundee to assist Cerebral Palsied children (typically diplegics) who exhibit a grossly disturbed gait pattern characterised by toe walking, generally jerky joint movements and poor balance. When applied to these patients the SAFO acts in a static manner to directly control the position of the ankle joint which is normally immobilised in a slightly dorsiflexed position. The action of the orthosis is immediate and results in a clear improvement of standing balance which is easily attributable to the resulting enlarged support area. More surprising is the dramatic improvement in the gait pattern which is smoother and more normal. Gait analysis studies have demonstrated that the orthosis is acting indirectly to modify the line of action of the ground/foot reaction force with a resulting reduction in the external moments at hip and knee. This indirect action of the orthosis is much more difficult to predict and has been found to be extremely sensitive to minor changes in the characteristics of the orthosis.

CONCLUSION

Further improvements in the function of orthoses will demand a systematic approach to the analysis of the clinical problem, the study of the interaction between orthoses and their users and the development of appropriate design criteria.

ADVANCED MODULAR ORTHOTICS

Richard E. Hannah
Medical Engineering Resource Unit, University of British Columbia
Vancouver, Canada

ABSTRACT - Advanced Modular Orthotics permits the rapid provision of definitive orthoses through the assembly of mass produced components into custom devices. This implies a redefined role for the orthotist and better functioning orthoses for the disabled.

RÉSUMÉ - Le domaine des orthèses modulaires avancées permet de fournir rapidement des orthèses définitives grâce à l'assemblage de dispositifs faits sur mesure à partir d'éléments produits en masse. Il en découle que les spécialistes de l'orthèse verront leur rôle redéfini et que les personnes handicapées pourront disposer d'orthèses qui fonctionnent mieux.

Modular Orthoses are widely used for a variety of common and well-defined disabilities. Currently, modular orthoses consist of discrete function modules: a knee hinge, a side bar, a dorsal pad etc. These prefabricated components can be assembled into certain selected orthoses and they reduce the amount of handwork required. The provision of completely prefabricated orthoses, such as some knee and drop foot orthoses, eliminate hand fabrication by the clinician.

However, the adaptability of these devices is limited by their size and by their design. One size fits no one. A large array of sizes may have to be stocked, and there will still be limitations in fit. In addition, an orthosis designed for a particular function usually cannot be used for anything else. A knee orthosis can only be used as a knee orthosis. The components of these orthoses have specific functions tied to the final function of the orthosis. A knee hinge can only usually be used as a knee hinge. Due to the size and discrete function limitations of each of the modules, current modular systems are orthosis specific.

The new generation of Modular Orthotics permits a wide range of orthoses to be constructed from a reasonable array of components, because the functions that are performed by each module are more generalized and less related to the final orthosis. As an example, the formation of a `T` junction between two structural members is a modular function not tied to the final structure of the orthosis. This building block is much like a house brick, which has no preconception of what the house will look like. Its function is to support its neighbour brick. If the bricks are arranged in a careful manner, the house will stand and function correctly.

Much is the same with a truly modular orthosis. The orthosis can be made to perform a selected function by the arrangement of the modules. The modules can be rearranged to permit the orthosis to perform a different function, as they are standard modules and not related to final form of the orthosis. A hinge now does not have to be specified as a knee hinge but simply as a hinge that can be used in various locations.

When the field of orthotics is reduced to this lowest common denominator it becomes truly modular.

Thus, true modular components must: have generalized functions; function independently of each other; be able to connect to each other ad infinitum; and be replaced without disturbing the whole.

The definition of an advanced modular orthotic system then becomes:

"a system of components whose structure and function is independent of the final design of an orthosis, and related only to the effectiveness of the system."

EXAMPLES OF ADVANCED MODULAR ORTHOTICS

The system of advanced Modular Orthotics developed at MERU, known as Tubular Orthotics (1), has been used to construct eight different orthoses from the same armamentarium of components. These orthoses are: a Torticollis collar for children; a Cervical Spine orthosis; a Thoracic Spine Flexion Resist; a Shoulder Abduction Orthosis; an Elbow Flexion Resist Orthosis; a Paediatric Wrist Orthosis; a Hip Abduction Orthosis; and a series of Pressure Sore Management Frames for the Lower Limbs.

FIGURE I

The most widely used Tubular Orthosis is the Cervical Spine Orthosis - the Canadian Collar. Over 200 have been distributed in kit form and fitted primarily to arthritis patients. An example shown in Figure I, is shown fitted to a child with juvenile rheumatoid arthritis. The orthosis is constructed from short lengths of nylon tube linked by `T` junctions to upper and lower perimeters of polyvinyl chloride (pvc) tubing. Assembly and fitting of this orthosis takes 30-45 minutes and the result is a cooler, more supportive orthosis with the improved function of resistance against flexion.

FIGURE II

A shoulder abduction orthosis is shown in Figure II. This has been used on burns patients for the stabilization of the shoulder following grafting procedures, and for the prevention of adduction contractures. Its adjustable nature enables fine tuning of the angle of shoulder abduction. The materials used are able to be sterilized, an important consideration in burns and post-surgical management.

The paediatric wrist orthosis shown in Figure III (right) has been used successfully on 10 children ranging in age from 7 months to 6 years, having either cerebral palsy or brachial nerve damage. The orthosis provides wrist extension yet interferes minimally with grasp or tactile input. A one size kit of components was used to fit all the children. The appropriate length of precut nylon tube was selected and joined to the encircling pvc tubing with connectors. As the children grew, the diameters and lengths of the components used were changed individually, without the need for replacing the whole orthosis.

FIGURE III

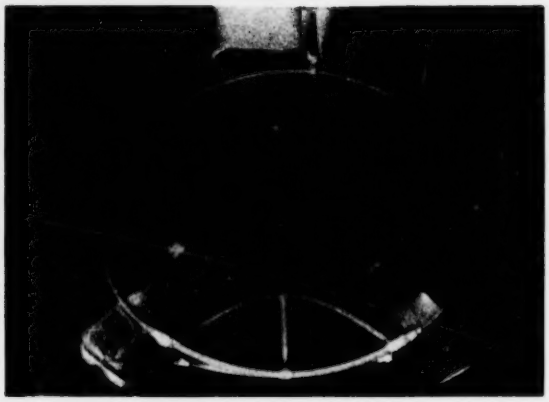

FIGURE IV

A hip abduction orthosis has been applied to children for the management of Legg Perthes, and to adults for post-operative management of the hip. One child supplied with the orthosis lived in a remote location. MERU worked from written dimensions and mailed the completed device, which was worn for 2 years. Other orthoses have been fabricated in clinical settings and fitted to patients for the stabilization of adductor tendon release, as shown in Figure IV. The result is a clean, durable and adjustable orthosis that provides minimal encumberance to a difficult to manage disability.

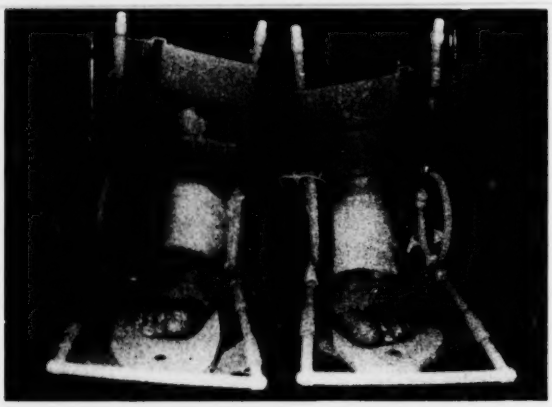

FIGURE V

A number of pressure sore management frames have been constructed from the Tubular Orthotics system. The example shown in Figure V is for the management of ducubitus ulcers of the heels. The frames allow accurate, repeatable positioning of the feet and provide weight relief to the heels. Frames have also been constructed for paraplegic patients confined to bed. Each case is different for this type of disability and custom frames are needed for each patient. The Tubular Orthotic system permits this custom fabrication from standard components.

The building blocks of the orthoses illustrated are tubes and connectors. The Tubular Orthotics system is a good example of an advanced modular orthotic system but it is not a definition of such. One could envision, for example, an orthotic system of flat beams and flat connectors; or rods and external junctions; or small spherical modules each connected directly to its neighbour. The new shapeable matrix seating systems are good examples of alternative modular orthotic systems using similar, repeating modules. With these modules, the same orthotic function may be achieved through several different configurations. It is this flexibility of design that helps to define advanced Modular Orthotics and gives it significant advantages over conventional approaches to orthotics.

ADVANTAGES OF ADVANCED MODULAR ORTHOTICS

The advent of advanced Modular Orthotics presents an opportunity to set new standards for orthotics.

These are set through: increased function for the patient; more efficient manufacturing; improved performance of orthotists; and simpler methods to teach.

Increased function for the patient is a result of the fine adjustment available to suit immediate and changing needs. Many conventional orthotic approaches require special facilities or tools to make adjustments. A truly modular orthotic system permits adjustments to be made in a patient's home or at a bedside. The orthotist is liberated from workshop dependent techniques, and so can give an immediate response. The techniques are reversible, so a degree of experimentation with the device on the patient is possible. Patient feedback can be responded to until the desired level of function is attained. The patient also benefits from devices that are lighter, leaner and more cosmetically appealing.

Standardization of components and dimensions permits the use of mass-production techniques established in other industries. For example, Tubular Orthotics uses standard industrial grade tubing; hardware from the electronics industry is employed wherever possible. When a specialized component is necessary, techniques such as injection moulding and die stamping are used to efficiently manufacture by the thousand. The result is low cost, interchangeable components which are readily available, disposable or suitable for recycling.

Of prime consideration is the newly defined role of the orthotist. The assembly of an advanced modular orthosis is an example of flexible manufacturing. Flexible manufacturing in orthotics facilitates mass production of custom orthoses by allowing the orthotist to organise and assemble modules into the desired orthosis. This rapid and flexible assembly procedure will free the orthotist from the problems of fabrication.

The orthotist will therefore have more time to consider the special requirements of each patient. His input in orthotic management will be more prominent as he will be able to suggest options and variations that would not be feasible with current orthotic systems.

The role of the advanced modular orthotist thus becomes one of: biomechanical evaluation of the problem; followed by, correct selection and assembly of components to resolve that problem.

This requires a great deal of skill, as a clear perception of the disability is needed, together with a good understanding of the function of each module and the biomechanical effect it will have. The orthotist will also function more effectively as an allied health professional due to increased visibility of the orthotist in the clinic team. Currently, orthotists are perceived as people who are called in, take measurements or a cast and then retreat to a workshop. This will change as advanced modular orthotics permit orthotists to implement solutions in a manner that is visible and understandable to other professionals.

The teaching of advanced modular orthotics is made easier than that for conventional orthoses because it can be grouped into two stages. Firstly, the general principles, including the structure, function and limitation of each module can be delineated in a discrete manner. The student will have a thorough understanding of the building blocks before he starts to build. Secondly, the protocol for assembly of the modules for an orthosis will be well-defined and adherence to the steps will result in an acceptable orthosis. However, the steps can be delineated in a manner that encourages experimentation. The structure of many modular orthoses is open-ended and the required function can often be attained through several different configurations. These lack of constraints in design and assembly will encourage innovation, secure in the knowledge that the process is reversible and `fail-safe`.

FUTURE DIRECTIONS FOR ADVANCED MODULAR ORTHOSES

New orthoses will emerge for disabilities where orthotic management has not been considered feasible. Advanced Modular Orthotics will also encompass areas such as seating, aids to daily living and mobility devices. One of the challenges facing this new generation of orthotics is expansion of the range of components to meet these new needs. For example, Tubular Orthotics does not address the problem of containment or encasement of a limb segment, necessary in the stabilization of fractures. New components or perhaps a new modular system will have to be devised to manage these types of disabilities. Also, certain components still have specific functions, such as chin supports, and they cannot function as general components. A more basic `common denominator` may be required for these particular functions.

The nature of advanced Modular Orthotics will lead to the definition of disabilities in `modular terms`. Instabilities, disabilities and immobilities of joints will be defined in engineering terms of degrees of freedom. The functions desired of orthoses will be classified according to the degrees of freedom they permit. This modular description of disabilities and their solutions will lead to use of computers to define the correct arrangement of components for more complex disabilities.

The centralised fabrication facility of the orthotist will be supplanted by a mobile work unit i.e. the orthotist him or herself. S/he will carry a stock of components in a travelling kit and assemble, rapidly, on demand, at first sight, the definitive orthosis. For certain well defined, common and easily managed disabilities, "cardboard cut-out", disposable orthoses will become the norm (2). However, custom advanced modular orthosis will be assembled and provided in a period of 30 to 60 minutes to meet specialised needs.

A new allied health professional will emerge to lead this 3rd industrial revolution in orthotics. He will be a new breed of `super-orthotist`, a combination of orthotist, therapist, rehabilitation engineer, designer and inventor.

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TESTING AND EVALUATION OF PROSTHESES AND ORTHOSES IN THE FEDERAL REPUBLIC OF GERMANY

U. Boenick
Technical University Berlin, Federal Republic of Germany

ABSTRACT - This paper describes the technical test procedures for orthopedic aids which are presently used in the Federal Republic of Germany. As the majority of tests is performed on extremity prostheses and crutches, this contribution is focussed on these aids. For orthotic devices similar procedures are used.

RÉSUMÉ - Cet article expose les procédés techniques pour les épreuves des moyens orthopédiques actuellement utilisés dans la République Fédérale Allemande. Comme la plupart des épreuves sont éxécutés avec les prothèses d'extrémité et les béquilles, cette contribution se concentre sur ces moyens. Des procédés analogues sont utilisés pour les dispositifs orthostatiques.

In the Federal Republic there is no general legal obligation to subject technical aids for the disabled to tests. The only exceptions are aids provided for war veterans, or their surviving dependents, within the framework of the Federal Welfare Act. The responsibility for implementing this act lies with the Federal Ministry of Labour and Social Affairs. In order to ensure that the aids provided are functionally perfect and fully developed technically, this Ministry has set up an advisory panel of rehabilitation specialists (Council for Orthopaedic Technology). This council recommends on the basis of test results, whether or not the Ministry should accept the aid for use by the Veterans'Service. The types of aids tested range from prostheses and orthoses, trough walking aids, wheelchairs, communication and orientation aids, to the socalled tools for living.

The evaluation procedure normally includes a technical test and a practical trial carried out on a limited number of disabled people.

A favourable outcome of the evaluation and testing procedure means only that the investigated aid will be recommended for use by the War Veterans' Service. But, in fact, other interested parties also make use of the results; for example professional associations and Social Insurance institutes, and to this extent the test results have a significantly wider application.

Besides the test already described, which are concerned primarily with questions of function, durability and wear, there is a second category of tests concerned exclusively with questions of safety. The background to these is the Technical Work Aids Act, which has more recently come to be called the Apparatus Safety Act. This act requires that the respective aid must be safe for the user and for third parties, in accordance with the accepted rules of technology.

The safety tests are carried out at the suggestion of the manufacturer by legally recognized testing centres. If the results are positive, the manufacturer of the investigated aid is granted the so-called Safety Logo, which he may then reproduce on every aid in the series. This logo is made up of the two letters G and S, which stand for the words "Geprüfte Sicherheit"(tested for safety), and the name of

the testing centre (Fig. 1).

Figure 1 Safety logo according to the Apparatus Safety Act (Testing Centre for Orthopedic Aids TU Berlin)

In order to illustrate the test philosophies as well as the test equipment now in use in the Test Centre for Orthopecic Aids in Berlin, where the majority of tests is performed, in the following sections the procedures for extremity prostheses and walking aids are described in detail.

Lower Extremity Prostheses

In order to establish test protocols for lower extremity prostheses, kinematic studies must be performed, to obtain the necessary data on the range of knee and ankle joint movements for functional and lifetime testing.

In addition data about the forces and moments acting on artificial legs are needed for establishing load patterns. For this purpose different techniques may be used. The first is employed in order to obtain analogue records, i.e. forces and moments as a function of time, while the other records only the peak loads of each step. In both cases shin tube pylons provided with strain gauges to obtain the axial load, the sagittal and frontal bending moments and the axial torque are employed.

A typical analoque record, obtained at a walking speed of 4.5 km/h is shown in Fig. 2.

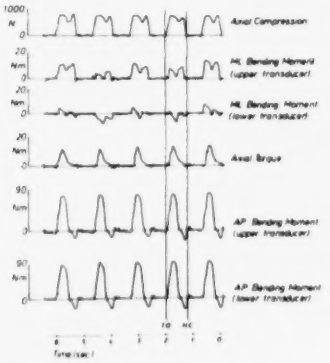

Figure 2 Typical load/moment record (walking speed = 4,5 km/h; Asphalt)

The second procedure provides information from normal daily use of the prostheses. For this purpose a histogram recorder consisting of an electronic measuring and storage unit is used. The advantage of this device ist, that it does not limit the ambulation area of the test person.

The histogram recorder basically consists of 6 strain gauge amplifiers, a classification circuit and 4 16 channel counters. In addition a microprocessor is needed to calculate the maximum bending moments at the knee and ankle during each stance phase, from the signals of the two superposed transducers in the sagittal and frontal planes.

To illustrate the results the frequency distribution of the axial forces, the bending moments at the knee and at the ankle and the axial torque from 29 subjects is shown in Fig. 3.

The measured data from various subjects in combination with the analoque

records mentioned above permit the development of lifetime test methods with loads of varying magnitude.

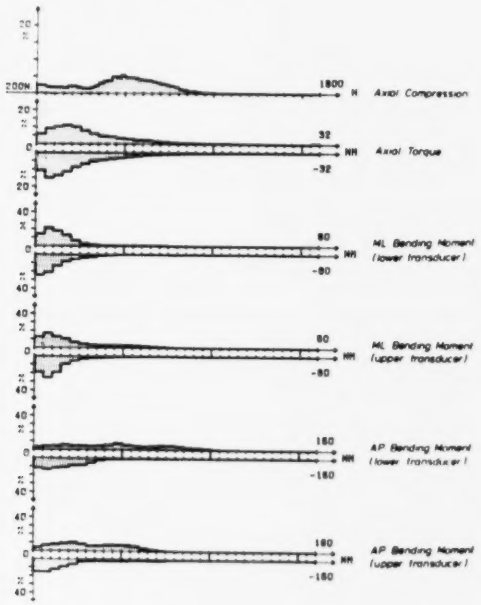

Figure 3 Frequency distribution of the maximum loads in AK prostheses (530 000 steps; 29 subjects)

Testing and evaluation normally starts with the determination of functional characteristics such as ankle deflection curves of artificial feet, effectiveness of knee break mechanisms, the knee moment distribution of swing phase control systems etc. In certain cases these investigations are completed by energy expenditure measurements on patients when wearing the test prothesis. This is followed by the lifetime test. For this purpose servo controlled hydraulically driven machines are used which duplicate the load and movement patterns obtained from the measurements described before.

Fig. 4 for example gives an overal view and of a knee testing unit of this type. The nominal load values, are stored in programmable EPROMs. As determined by these data the required hydraulic output is produced via servo valves. The system operates in closed loop control.

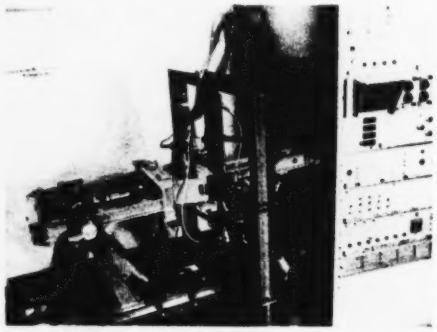

Figure 4 Total view of a servo hydraulically controlled knee test machine

Hand and Arm Prostheses

To provide a basis for technical testing and evaluation of hand and elbow mechanisms measurements were again carried out on amputees. This was expected to provide the necessary data on the number of daily movements, the average range of movements, and the exerted forces and moments, respectively. To illustrate the results obtained from these experiments Fig. 5 shows for example the frequency distribution of daily gripping movements of electromechanically powered hands. This graph is based on data obtained from 70 patients.

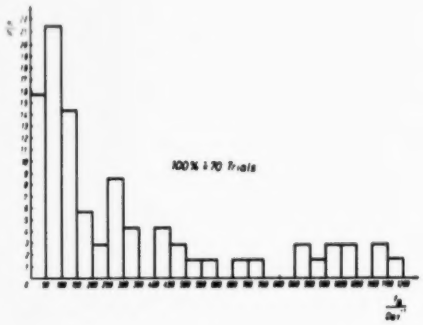

Figure 5 Relative frequency distribution of daily grip movements of electromechanically powered hands

Similar to leg prostheses, laboratory tests for upper extremity prosthetic components are started with the determination of functional data i.e. gripping forces, elbow moments, range of movement, energy consumption and speed in externally powered systems, operating forces and transmission ratios in body-powered systems etc.

This is followed by the lifetime test. Fig. 6 shows an overall view of one of the test devices used for externally powered hands.

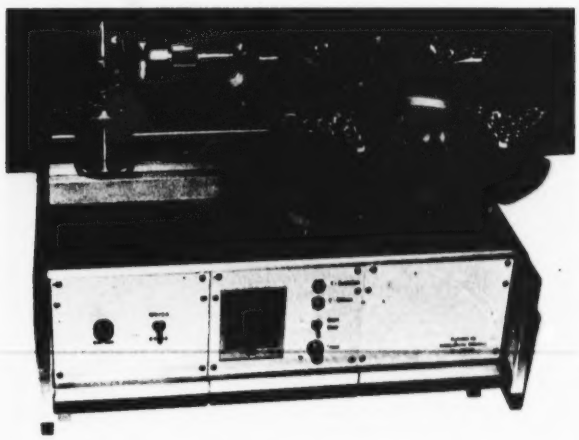

Figure 6 Equipment for dynamic testing of electrically driven hand mechanisms

Walking Aids

The testing of walking aids is presently concerned mainly with forearm crutches. Before establishing a test protocol again biomechanical studies were carried out in order to investigate the stress distribution within the device during different walking activities. For this reason crutches were provided with strain gauges at various points. Tests were performed on a treadmill with unilateral and lilateral amputees.

From their results the average resultant force acting on the handle was calculated to be about 500 N. This figure is used as the maximum dynamic force. During the test the force periodically increases linearly up to this point, and then decreases to zero, at a frequency of 5 cycles per second. The total number of cycles is 1.5 million.

For performing the dynamic test a single-channel closed loop controlled servo hydraulic test machine is used (Fig. 7). The nominal values are generated by a saw-tooth generator, while the actual values are measured by a strain gauge force transducer.

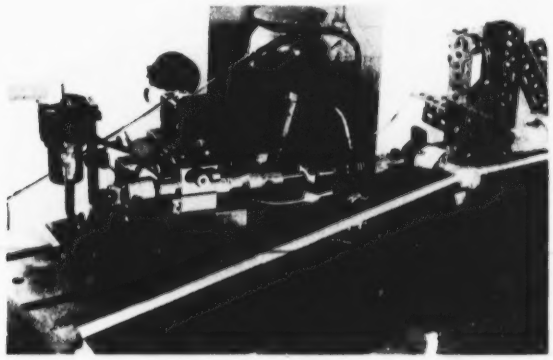

Figure 7 Total view of the test arrangement for crutches

In addition to this dynamic test a static test is carried out in order to determine the point of beginning plastic deformation. This should not happen at less than 1000 N. Up to 2500 N no fracture should occur.

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MYOELECTRIC FITTINGS - THE ITALIAN EXPERIENCE

Prof. Hannes Schmidl
Centro Protesi INAIL 40054 Vigorso di Budrio, Italy

ABSTRACT - The following describes the experience and results of the INAIL Prosthesis Center at Budrio, Italy, with myoelectric prostheses for one or both upper limbs in congenitally malformed or amputee adults and children. The various aspects are discussed including ongoing research into the possible use of nerve potentials.

RÉSUMÉ - Il analyse les résultats et les expériences du "Centro Protesi INAIL", Budrio, Italie, obtenus grâce à l'utilization de prothèses myoélectriques remplacant l'un ou les deux membres supérieurs chez les adultes ou les enfants qui ont subi des amputations ou qui présentent des malformations congénitales. Il examine des differents composants et se rapporte à la recherche en cours sur l'utilization du potentiel du nerf.

Italy, or more precisely, the National Institute for the Prevention of Industrial Accidents - for brevity's sake, INAIL was a frontrunner in the development of myoelectric prostheses.

As far back as 1964 the INAIL Prosthetics Research Center at Vigorso di Budrio was fitting upper-limb amputees with myoelectrically controlled prostheses.

Over the past 20 years great strides have been made even if it must be admitted that upper-limb prostheses is still not a trouble-free area.

Fitting an upper-limb prosthesis is a complex matter not only because function is restored by means of an artificial limb but especially for the difficulties entailed in controlling such functions and in supplying the energy to bring about movement.

To fully appreciate the complexity of building an artificial upper limb, let us first consider how this limb works. Human limbs comprise a perfectly integrated system at various levels for movement and its control, with a network of information receptors linked by myriad efferent and afferent information channels.

It is not surprising, therefore, that injury to even a minimal part of this biologic system as a result of malformation, disease or trauma will impair this flow of information.

Hence detailed study of the natural limb is essential before designing an artificial one, especially an upper-limb.

Only then will it become evident how to bring stump and prosthesis into contact to articulate the various elements and thereby, at least partially, restore natural function.

Obviously the ideal solution in the event of a missing limb would be being able to actually regenerate a new one in its place.

At the present time, however, this is unfortunately not biologically possible and artificial solutions must be sought that are as close to the natural arm as possible.

The rapport between man and machine is fundamental to prosthesis control. This relationship has two main features:

1) stump viability. This is obviously a surgical problem to provide stumps with stability between antagonistic and agonistic muscles so as to ensure confident control of stump functions;

2) Perfect fit between stump and socket to allow stump movements to be transmitted to the artificial limb.
If the fit is imperfect, setting up a pseudarthrotic movement between stump and prosthesis, the workability of the prosthesis is greatly reduced.

So much for prosthesis control.

The individual movements of, for example, hand, wrist, elbow and shoulder, afford greater functional possibilities the more intimately theircontrol is linked with the rest of the amputee's body.

In wrist disarticulations and lower third forearm amputees the stump can be actively used to induce pro - and supination of the hand by means of a rotation mechanism. In the forearm amputee wrist flexion and extension are missing and are compensated for by rotation of the unit, depending on the gripping angle of the manipulator or hand, through a full 360°.

Depending on the level of amputation, the elbow joint can be either a kinematic or an electrically controlled mechanism.

The stump should, however, have some part in prosthesis control for only in this way will a close link be achieved between prosthesis and amputee, leading to greater use by the amputee of his artificial limb.

The individual components - hand, wrist, elbow etc. - are controlled by systems intimately connected with the amputee himself, such as myoelectric control or, in some cases of congenital malformations, electronic microswitches or microsensors.

As well as providing greater gripping sensitivity and command over the various elements, myoelectric control has notably increased the use made by the amputee of his prosthesis not only for the greater functional possibilities afforded but also for the closer rapport between man and machine, prosthesis and amputee.

This rapport is further enhanced by another important factor - the more reassuring outward appearance of this prosthesis.

It is well known that outward appearance plays an important role in amputee acceptance of and participation in his functional rehabilitation through a prosthesis. Indeed this aspect was amply taken into account when designing our model.

If an amputee is to make the best possible use of his upper-limb prosthesis the following 4 factors must be assessed:

1) viability and wearability
2) performance
3) durability
4) outward appearance

1) Obviously the care with which the prosthesis is fitted and its weight are fundamental to how functional and wearable it will prove to be.

Other factors are often overlooked despite their importance to the overall success of the unit: for example, movement that is natural and can be efficiently controlled will generate that interchange of information that makes the trouble taken in the learning phase worthwhile, furthermore allowing the prosthesis to move smoothly and in synchrony with the rest of che amputee's body.

Moreover the various devices have been designed to give swift movement, thereby bridging as far as possible the gap between natural and artificial limb. With the right control systems and mechanical units an artificial limb can become an integral part of the amputee's body and not just a stiff mechanical appendage.

2) Performance. The level of prosthesis performance depends both on the system of control - which records the amputee's intention - and on the mechanical unit which actually carries it out. It must be stressed that unless both these areas are satisfactorily catered for - a good control system together with good mechanical parts - the results will be disappointing.

The control system receives signals - either myoelectric or electromechanical - from the amputee which it duly processes into a series of logical information for the prosthesis to obey. The control system must also check that the prosthesis functions are those actually requested.

In practical terms, the control system has to establish what the patient wants to do with his lost limb did he still possess it, and send on instructions to the mechanical parts of the prosthesis to make them execute his intentions.

The mechanics of the prosthesis must be compatible with such a sophisticated control system, permitting the widest range of dynamic movement along with sufficient force.

The whole system must be autonomous, light-weight but at the same time able to stand up to the stresses and strains of continuous use.

3) Durability: as a rule total amputee acceptance of an upper limb prosthesis depends on this being worn and used

Comparative studies of the natural and artificial limb at the prosthetics Research Center at Vigorso di Budrio and elsewhere provided a detailed description of what a good prosthesis should offer, given the technical possibilities available today.

On the basis of these indications an upper-limb prosthesis was developed and tried. Today it offers maximum performance and is fitted routinely.

Particular study went into the question of grip - by the hand or manipulator, a gripping device to enable work; mechanical articulations for the whole arm; the relationship between man and machine, amputee and prosthesis and control mechanisms for the individual components.

It became evident that an artificial, multi-articulated hand such as would afford the amputee greater self-reliance and allow him to take an active part in social and work-a-day life, is not yet feasible.

Experimental models of multi-articulated hands do exist but todate they have proved unsatisfactory for the following reasons:

1) the energy/force ratio does not give sufficient grip strength to allow the amputee to carry through a task;

2) rapid wear on account of the large number of highly complex mechanical articulations;

3) independent control mechanisms for each finger movement are not as yet possible given the limited space of the hand which would have to house these controls; furthermore, these individual mechanisms should be controlled by a higher unit, which again is not yet feasible.

There are a few experimental myoelectric multi-articulated hands with suspensio-strap alignment linkages controlling the mechanisms on the three main gripping fingers - thumb, index and middle fingers; the 4th and 5th fingers wrap round the object at the same time. However, this mechanism does not provide sufficient gripping force which should be around 8 Kg.

So the main drawback of these multi-articulated hands is their lack of prehension force hand this is why they are not used.

Another drawback is the cosmetic glove: the covering glove itself sets up counter-resistance to the multi-articulated movements.

The artificial hand in use today provides a single gripping movement of thumb, index and middle fingers and the resultant energy/gripping force ratio is excellent. This is especially due to the fact that there are only two mechanical axes compared to the 14 needed on the multi-articulated hand. Gripping force is around 10 Kg. which ensures absolute control.

The hand can open for a span of more than 100 mm with a depth of some 60 mm, meaning that all types of objects can be grasped.

This hand is made up of 3 components- the mechanism, the motor and the skeleton. The hand itself is of soft material onto which an interchangeable glove is moulded which avoids any counter-resistance or deformation of movement.

The latest development is an electric manipulator similar to a mechanical hook for work purposes. It can be swiftly interchanged with the hand piece and fitted onto the prosthesis. The result is greater efficiency in manual, mechanical, agricultural or other types of work.

The manipulator grips with a parallel jaw-like movement. This mechanism allows the amputee to grip very small as well as large objects requiring a gripping force of as much or even more than 12 Kg.

Hand span and depth are well balanced, meaning that spherical or round objects of more than 100 mm diameter can be satisfactorily held. Speed of both manipulator and hand is up to 20 cm per sec. approximately. Myoelectrically controlled commands are also available for proportional control over speed.

For speeds of more than 20cm per sec. a feed-back mechanism to the central control is needed. This might in the future be supplied by nerve potentials, an area of ongoing research which I will deal with in my conclusion.

Of fundamental importance is an electric wrist joint for bilateral amputees, be they middle third forearm or interscapulartheracic cases.

for about 4,500 hours a year or more than 12 hours each day.

All components must be heavy duty elements able to withstand the exceptionally tough working conditions, including involuntary damage, and provide reliable service. When needed assistence and repair must be immediately forthcoming so as to ensure that the amputee never has to be without his prosthesis.

Prostheses that often go wrong or break cause psychological damage which is much more severe as it may lead to patient rejection.

4) Outward appearance: this is extremely important both for the patient and those around him.

Outward appearance includes a series of factors such as cosmetic improvement and movement flow, which must be as close as possible to the natural limb but not subtract from the functional possibilities to achieve this.

The prosthesis should be as noiseless as possible, keeping inevitable noise regular in tone without those peaks that set off the typical buzzing sound.

If the indications I have illustrated above are included into an upper-limb prosthesis, then it is highly likely - indeed almost certain - that it will be a success, provided, of course, that the amputee collaborates.

Another area requiring upper-limb prostheses is children with congenital malformations. The numbers vary from country to country but are nonetheless considerable.

Treatment must start no later than twelve months of age, with increasly complex prostheses being fitted as the child's learning ability increases.

In the last 3 year we at the Prosthetics Center at Vigorso di Budrio have developed components for a treatment program for children with various types of malformations that takes the infant in need of prosthesis right through to adulthood.

Research - and thus the resultant components - focused on prefabricated components needed to set up a program for the child from infancy to full growth.

These components are geared especially for bi-lateral congenital amputees starting from 15 months to 6 years.

Previously, functional prostheses were not available for this age group. Instead of an artificial hand, small children do particularly well with the following type of electric hook:

- 3 Kp gripping force,
- gripping speed of 8 cm per sec.
- maximum opening or span 40 mm.

Wrist articulation can be either by passive friction or electric; range of motion of the elbow is from 0 to 130° with a maximum-flexion-through-maximum-extension speed of 1.8 secs.

This is a modular system built into a light alloy and titanium frame and run by 6 Volt rechargeable batteries.

The soft material covering has a threefold function: attractiveness, protection of the prosthesis and protection for others, especially playmates.

The whole prosthesis weighs 430 or 480 grams depending on whether the wrist unit is a passive friction or electric articulation.

Children without both upper limbs are fitted with a functional prosthesis on one side only; contralaterally, an esthetic prosthesis with battery and electronic control is applied.

This latter prosthesis weighs a total of about 400 grams.

In this way myoelectric and electronic controls can be combined.

With the aim of keeping the system within the intellectual reach of a child, a three microswitch electronic control was developed. Two switches control related movements such as opening and closing of the hand, pro and supination and flexion and extension of the elbow. The third selects the component.

The whole system can, of course, he supplemented with other existing components such as small electric hands etc.

These systems allow a progressive approach which matches functional complexity to the physical and mental development of the child.

(Case series using myoelectric and electronic prostheses.)

Today myoelectrically controlled prostheses have reached such a high standard of performance that any subsequent improvement must entail the use of neuroelectric control. In this case the direct contact between amputee and his prosthesis would be accompanied by a return of information - especially important for the hand - known as Bio-Feed-Back.

Such an achievement would very probably allow improved speeds, more accurate movements and better coordination between the movements of the hand and the other articulations, which today do not compare with the performance of a natural limb.

Putting epineural signals to use is not easy nor is it impossible, as Prof. Stein of Alberta University showed a few years ago. The interdisciplinary research group at the INAIL Prosthetics Center at Vigorso di Budrio has succeeded in obtaining a potential from the epineurium of a peripheral nerve trunk and bringing it to the surface where it can be received by electronic amplifiers.

Obviously we are a long way from any practical application of this epineural signal to control prosthesis movement, but the seed has been sown and we are convinced that prosthesis control via nerve potentials will one day be a reality.

What is certain is that further improvement in prostheses - especially upper-limb prostheses - depends on inreasingly close collaboration between medicine and bioengineering since the road to better control - especially in the case of the hand - lies in integrating prosthesis control and the amputee's own body.

This should also open the way to a multi-articulated hand since coordinating the movements of five separate fingers would be more feasible. A multi-articulated hand, however, also awaits technological developments in mechanics to provide micro-motors and micromechanisms for better gripping force, speed and higher force/energy ratio.

In conclusion, the field of upper-limb prostheses is the object of a great deal of research which has furnished excellent results in recent years. And, as we have heard, the problems are many, related not only to the commitment of the individual researcher but also to technological advance and the development of new materials.

RESEARCH DIRECTIONS IN MYOELECTRIC PROSTHESES

R.N. Scott
University of New Brunswick, Fredericton, NB, Canada, E3B 5A3

ABSTRACT - Beginning with a brief overview of developments in myoelectric prostheses since 1948, this paper describes present research and identifies trends which indicate the probable direction of future research.

RÉSUMÉ - Cette communication retrace l'évolution des prothèses myoélectriques de 1948 à nos jours et décrit la recherche actuelle. Elle identifie également les tendances qui orienteront probablement les recherches futures.

INTRODUCTION

The concept of a myoelectric prosthesis is very simple: the electric activity of a muscle is used to control the flow of current from a battery to a motor-driven appliance. To understand the complexity of the problem and to place present research trends in perspective, it is necessary to review 35 years of development.

HISTORICAL DEVELOPMENT

The first myoelectric prosthesis was developed by Reiter in Munich, in 1948 [1]. It was not until 1969 that this work came to the attention of the research community [2]. By that time independent research on myoelectric control had begun in the USSR [3], England [4], Sweden [5], Japan [6], the USA [7], and Canada [8]. The USSR myoelectric prosthesis was in domestic clinical use and being exported to Canada and England, and collaboration with Otto Bock Orthopadische Industrie KG had resulted in a system for clinical use in the I.N.A.I.L., Italy [9].

CLINICAL ACCEPTANCE

Clinical acceptance of early systems was marginal at best, a fact which is readily understandable when one considers their problems of size, weight, performance and reliability. The turning point contributing to widespread use was further development by Otto Bock, leading to a modular system very similar to the one now supplied by that firm to the vast majority of users of myoelectric prostheses. The contribution of Childress [10] in emphasizing the need to make myoelectric prostheses self-contained, self-suspending and of good cosmetic quality also was critical.

It is generally agreed that the rejection rate for conventional prostheses among unilateral below-elbow amputees is high: Vitali et al. cite a 67% rejection rate [11]. By contrast, published data for myoelectric prostheses cite rejection rates ranging from 0 to 20% [12-14]. Here the good function and cosmesis, freedom from suspension harness and ability to function throughout a wide range of positions are found to offset reduced speed, increased cost and weight.

In general, acceptance by bilateral amputees and by those with high levels of amputation has been less widespread. Here the need is greater, but the prosthesis is much less adequate in terms of function and weight.

Reliable data on the number of myoelectric prostheses fitted are difficult to obtain. In North America the present rate is about 600 per year, with per capita use in Canada running about twice that in the USA.

Recently there has been a trend toward very early fitting of congenital amputees with myoelectric prostheses. Initiated by Sorbye [15] the rationale is that having the myoelectric prosthesis during the period in which the child's perceptual motor skills are developing will lead to optimum use later in life. Results with patients fitted as young as 18 months of age and evaluated after ten years are impressive, particularly in terms of spontaneity of use of the prosthesis in bimanual tasks.

Another trend has been toward early

fitting of patients with acquired amputations. Here the work of Malone [16] is significant. There appear to be very substantial advantages to having the patient fitted either immediately following surgery or within a few days.

RESEARCH EMPHASIS

Perhaps one of the most important aspects of myoelectric control systems development will prove to be the resulting research on the process by which the myoelectric signal is generated and controlled. Here the work of Lindstrom and Magnusson [17] and of DeLuca [18] is significant.

Investigation of the theoretical basis of myoelectric signal processing followed the success of early clinical work which had been based upon empirical techniques. Here one might cite the work of Parker [19] and of Hogan [20] as significant examples. Study of the characteristics of the human operator as a controller of myoelectric output signals has not advanced as far [21].

The outcome of this research into the myoelectric signal, its generation and its processing, and into the characteristics of the human operator as a controller of myoelectric signals, has been primarily a gradual improvement in the performance of myoelectric control systems. This has complemented significant improvement in the performance and durability of electric hands. As well, clincial experience in myoelectric prosthesis prescription, fitting and training has expanded. Together, the result is a reasonably acceptable below-elbow prosthesis.

For higher levels of amputation, new concerns arise. First, most of the simple electromechanical actuators developed over the past three decades are totally inadequate. Notable exceptions are electric elbows developed in Boston (the "Boston Elbow") and in Salt Lake City (the "Utah Arm"). Here, finally, are realistic substitutes for the function of the amputated joint.

A second concern is how to control an increasing number of degrees of freedom with a decreasing number of muscle remnants as the level of amputation rises.

The concern for control of more than one degree of freedom per muscle remnant is as old as myoelectric prostheses. Reiter, in 1948, used one muscle to control both opening and closing of an electric hand [1]. His scheme, which differentiated between rapid and slow contractions to select the desired output, has reappeared recently in the Otto Bock single site control system. Independently, a multi-state system in which the output function depends upon the size of the myoelectric signal was devised by the author in 1965 [8] and is used quite widely in North America.

But more sophisticated control techniques are needed. One turns to the early work of Finley and Wirta [22] for the original research on control of multifunction prostheses by recognition of naturally-occurring patterns of activity in stump muscles. The concept is attractive, and is the basis of control of the multifunction SVEN hand developed in Sweden.

An alternative technique is to select, by relatively simple means, one of a variety of complex programmed functions. Initiated by Reswick in 1961 [23], this concept has become more practical with the development of microprocessors.

Finally, while the early excitement about using single motor units within a muscle remnant as multiple control sites has faded, a sophisticated signal processing technique proposed by Graupe [24] may permit identification of several patterns of muscle activity at a single site.

Two other aspects of research deserve mention: sensory feedback and surgically implanted telemetry. Realization of the need for some substitute for sensory feedback has led to research by the author and others [25 - 28] but as yet has not yeilded a practical system.

One difficulty of sensory feedback systems - conveying information to the central nervous system - would be facilitated if direct connection to peripheral nerves were possible. This is one objective of research on surgically implanted telemetry systems. The other objective is to permit direct connection to muscle and/or nerve control sites. Research has been sporadic, and has included investigation of passive implants[28, 29] as well as active implants [30 - 33]. A primary obstacle at present is the need for an improved method of protecting the implant from its moist surroundings.

FUTURE TRENDS

For below-elbow amputations, the next decade will see growing acceptance of myoelectric prostheses, by patients, physicians, prosthetists, and third-party payers, to the point where what are now

called "conventional prostheses" will become the exceptions, used only in unusual circumstances. There will be some stabilization of opinion on the optimum age of fitting in congenital limb absence, probably at about 18 months. Early post operative fitting in cases of acquired amputation will become more common. Myoelectric fitting will continue to be done primarily in centres where a multidisciplinary clinic team can offer true competence in all aspects of the service. The concept of 'limb banking', will be extended to a wider age range in these centres, with some cost saving.

For above-elbow amputation, the use of hybrid systems involving devices from a number of suppliers will become more common. This will be facilitated by greater attention to equipment compatability. On-board microprocessors will be used to make the system adapt automatically to the changes in signal level associated with fatigue or changes in interference from the environment, and to permit selection from a number of pre-programmed functions. Within the decade, surgically-implanted telemetry systems for control and feedback will be introduced for clinical evaluation.

The outstanding problem still facing us at the end of the decade will be the need for a functional prosthesis to replace the complete arm and shoulder. It is unlikely that progress in energy storage and actuator systems will be adequate to make such a prosthesis feasible.

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AUTOMATED PROSTHETIC FITTING

C.G. Saunders and G.R. Fernie
Medical Engineering Resource Unit, University of British Columbia
West Park Research, Department of Surgery, University of Toronto

ABSTRACT - A system for computer-aided design and manufacture of prosthetic sockets is described. The elements include automatic high-speed shape sensing of the residual limb, interactive shape modification software, numerically controlled carving of the mould, and automated vacuum forming of the socket.

RÉSUMÉ - On décrit un système de conception et de fabrication assistées par ordinateur d'emboîtures de prothèse. Les différentes parties de l'opération comprennent la détermination automatique à grande vitesse de la forme du membre résiduel, un logiciel interactif pour modification de la forme, le découpage par système numérique du moule et la formation automatique sous vide de l'emboîture.

Introduction

In rehabilitation, the effective treatment of many disabilites relies on a systematic approach to handling shape. The present system in prosthetics depends to a large extent on artisan methods. The high skill operations of shaping sockets and cosmetic restorations are not easily mastered. As a result, expertise is gathered slowly by novice prosthetists and the quality of shape dependent prosthetic components varies widely from prosthetist to prosthetist.

The procedure of constructing a prosthetic socket can be thought of as a SHAPE MANAGEMENT PROCESS. The components of this management process include: (1) sensing the shape (in current practice by making a cast or making an impression), (2) establishing the shape model (by casting a model inside the impression), (3) modifying this model or replica to make it suitable for construction of the socket, (4) fabricating the final socket (by laminating over the model).

The Proposed Solution-A Shape Management Plant

It is suggested that the solution to the clinical shape management problem lies in the implementation of a SHAPE MANAGEMENT PLANT. This plant would have three components:

(a) a device which can sense anatomical shapes
(b) a method for systematically modifying shape
(c) a machine which can replicate the desired shape.

This paper describes a collaborative program where West Park Research is responsible for the shape sensing component and the Medical Engineering Resource Unit is responsible for the shape modification and shape application aspects of the shape management plant.

Shape Sensing At West Park

A shape sensing instrument has been designed using a concept that is applicable to the measurement of different parts of the body. The first instrument has been configured specifically for the measurement of trans-tibial (TT) amputation residual limbs and is shown in figures 1 & 2. The amputee sits on a wheeled seat that is pushed over the instrument. A cylindrical lens is used to project a vertical line of laser light onto the residual limb. Video cameras view this line from an angle and the locus on the video image is obtained in digital form. The line of light is caused to rotate around the residual limb which is viewed by an array of stationary cameras in order that the whole surface may be measured. The actual measurement process is completed in 0.6 seconds and the shape is represented by up to 17,280 sets of cylindrical polar coordinates.

Once the shape is measured, it is stored on computer magnetic media and can be retrieved and displayed as a three dimensional image. This measurement data can then be used as input into the computer-aided design process. When the amputee returns at a later date, his current shape may be compared with this earlier shape and appropriate changes to socket fit may be recommended.

Figure 1. The shape sensor

The shape sensor provides the opportunity of quantifying the existing manual shape measurement process. In addition to measuring the amputee, the shape sensor has also been used to measure the plaster replica before and following shape modification by the prosthetist. Data derived by this means will be used to refine the shape modification software. In essence, the computer will be learning from the experience of prosthetists so that it can respond more flexibly and reliably to a wide range of "non-standard" amputation residual limbs.

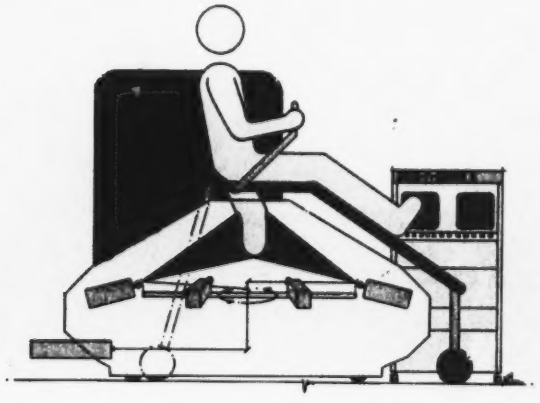

Figure 2. The amputee on a wheeled seat is positioned over the shape sensor with his residual limb in the optical scanning field.

Computer-aided Socket Design

The computer-aided socket design (CASD) software package is comprised of three major building blocks: a modelling component, a viewing facility, and an interactive modification capability. In the CASD system a reference TT socket shape is modelled as a set of points in a cylindrical coordinate system. Viewing is accomplished by allowing the operator to select, via an on-screen menu, which cross-section of the shape he wishes to see displayed. The interactive modification tools consist of an on-screen, movable cursor and a digitizer. These provide the operator with a means of altering the reference socket shape.

The CASD system, presently organized for the design of TT prosthetic sockets, provides 3 types of modification: (a) scaling, (b) tapering, and (c) patching. Scaling involves sizing the reference socket shape up or down according to measurements taken around the knee and down the residual limb. Tapering is required in order to account for differences in tissue bulk between the residual limbs of different amputees. It is used distally, and acts in such a way as to compress tissue areas and leave bony areas unchanged. The third type of modification, patching, is used in situations where more relief is required over bony prominences or more pressure is required on tissue areas, see for example figure 3. Patch modifications rely on operator judgement rather than physical measurement.

This design system has the advantages that (1) shape information on a socket is obtained for future use, (2) modifications to socket shape can be done interactively on a graphics screen, (3) mistakes made on trial fittings can be easily corrected, and (4) no messy plaster is required. Plans are to extend capabilities of the system so that trans-femoral sockets and cosmetic restorations can also be designed.

Written in PASCAL, the CASD package operates on an IMS 8000, Z-80 based microcomputer running the Turbodos operating system. The graphics hardware is the SCION MicroAngelo graphics board and a video monitor. The CASD software is now being enhanced in order to be compatible with the IBM XT Personal Computer.

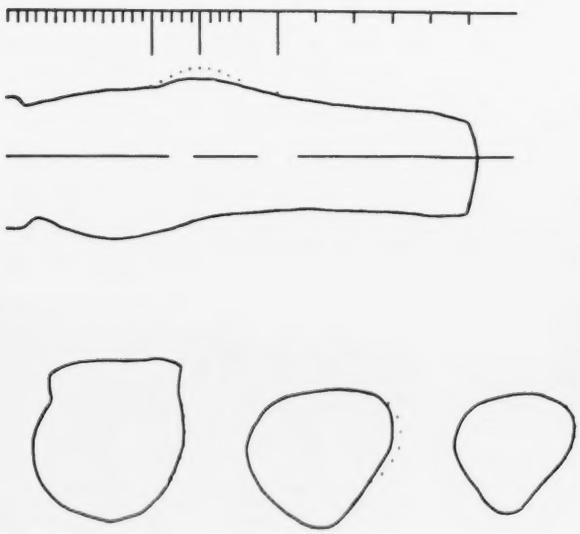

Figure 3. The computer displays longitudinal and transverse sections of the residual limb. The dotted lines indicate shape modifications of the head of the fibula to give more relief.

Computer-aided Manufacture of Prosthetic Sockets

Given that a socket shape can be designed on the computer, the next step is to obtain three-dimensional reproduction of that design shape. As a supplement to the CASD package, software has been developed which transforms the numerical definition of a socket shape into code which instructs a computer-numerically-controlled (CNC) milling machine to reproduce that shape. In this manner, a positive mould of the socket is carved.

The CNC code is transferred to the milling machine from the computer via an RS-232 serial link. The entire program is loaded into the memory of the milling machine. The machining technique is referred to as "mill turning" (1). A polyurethane or wax blank is mounted on a rotary axis. During carving, a ball-nose cutter moves up and down as the rotary axis turns and the bed moves along. Thus, the cutter actually moves through a "helical guide" as it traces out the surface of the shape. Corrections for possible undercutting of steep or doubly curved surfaces have already been provided by the software. The NCN machine is shown in figure 4.

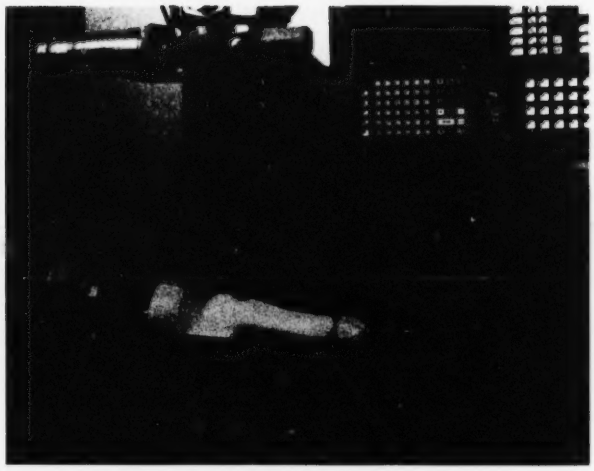

Figure 4. A finished carving on the numerically controlled milling machine.

The milling machine has three-axis simultaneous control and as a result, the models produced are reasonably smooth. The small spiral ridge which appears on the carving can be removed by doing a second pass of the shape with a large diameter cutter. This cutter starts with a horizontal offset of half the helical pitch of the first pass.

The carved model can then be placed inside a Rapidform* vacuum forming machine, see figure 5. The entire vacuum forming process is controlled by an on-board microprocessor system. Temperature and pressure inside the oven are monitored continuously. At precisely the right moment, the carving is pushed up inside the oven. The vacuum then draws a polyurethane preform over the model. After a preset cooling period, the door to the vacuum former can be opened and the formed socket shape withdrawn. A minimal amount of hand work is required to do final trimming.

Discussion

The proposed Shape Management Plant is capable of dealing with many shape related problems. Since the capacity to design TT socket shapes is already available, the logical extension to the system is to include the capacity to design trans-femoral, ankle disarticulation, and upper extremity socket shapes. It will also be possible to cosmetically finish the prosthesis based on a specified alignment.

The organization and setup of a Shape Management Plant is quite flexible. The plant has been envisaged as a compact unit where all three blocks would be found in a clinical facility. However, there are other options; the computer could be centralized and be tied into shape sensors and replicators in the clinical facilities. Alternatively, both the computer and the replicator could be centralized. Sensing could be performed in the clinics and shape data could be sent to the central facility. Finished shapes or shape components could be mailed back.

The most important feature of an automated shape management process is that data can be stored and retrieved very easily. With a client's original shape data on file, modifications can be added to his shape at each subsequent visit. Also, shape dependent prosthetic components which wear out can be easily "recalled" and therefore easily replaced. In this manner, the client is assured of a progressively better fitting socket and the prosthetist is assured of considerable time savings for subsequent fittings.

Automation of prosthetic design and fabrication procedures will speed up the prosthesis delivery process. A uniform and high quality service, over a large geographical area, will be assured. Standard shapes will develop from accumulated anthropometric data which will further enhance speed and quality. People with special needs will also be better served since the proposed system provides for the ultimate in customization.

In summary, automation of the shape management process will capture the important aspects of the current artisan methods and overcome their inefficiencies. Benefits of this approach include improved comfort for the amputee, reduction of costs, acceleration of prosthesis delivery, and uniform quality of the product.

Figure 5. A vacuum formed socket beng removed from the Rapidform machine.

Acknowledgement

The authors gratefully acknowledge the efforts of James Foort who layed out much of the groundwork for this approach. We would like to thank Ron Davies and colleagues of the University College in London for lending us one of their Rapidform machines. This program of research in Vancouver and Toronto has been supported by the National Health Research and Development Program of Health & Welfare Canada.

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*Rapidform is supplied by the Bioengineering Centre, Department of Mechanical Engineering, University College London, Roehampton Lane, London, SW15 5PR.

SPECIAL SESSION/SÉANCE SPÉCIALE 9

BLIND, VISUALLY IMPAIRED/

TROUBLES VISUELS

Chairperson/Président:

J.C. Swail
National Research Council Canada
Ottawa, Canada

THE STATE OF SPECIAL TECHNOLOGY IN THE UNITED STATES - TOTAL BLESSING OR MIXED BAG OF TRICKS?

H. Lauer
Edward Hines Veterans Hospital, Hines, Illinois, U.S.A.

ABSTRACT - Communications, that is, the ability to read the printed page or a video display screen, is probably the most severe problem facing a visually handicapped person in the work place. A brief summary is presented of reading machines, speech compressors, and special computer access systems. These include synthetic speech, Braille, and a large character video display.

RÉSUMÉ - La communication, c'est-à-dire la capacité de lire une page imprimée ou un écran vidéo, est probablement le plus grand problème qui se pose à une handicapé visuel dans le milieu de travail. Le présent mémoire décrit brièvement des machines à lecture, des compresseurs de la parole et des systèmes spéciaux d'accès aux ordinateurs. Citons entre autres la parole synthétique, le Braille et un écran vidéo à gros caractères.

We have done a lot, but how much have we done right? We have designed many machines and built quite a few, but how useful are they? Is useful technology being effectively deployed? Those are the questions I shall addresss.

I will do the best I can. Nobody knows it all. Nobody could. Since 1964, I have used, tested and taught eight models of reading machines, seven speech compressors, six braille and talking calculators, five speech devices, four braille devices, and a robotic cartridge in an apple tree, so to speak. I have also worked with many ordinary off-the-shelf solutions to meet special needs. Now computer aids are so much in demand, and they occupy so much of my attention, that I shall give them the most coverage but discuss them last.

Reading Machines

Two reading machines are available. Several thousand people in the U.S. have Optacons. It isn't known how many use them effectively. The Optacon is a $4,000 reading aid made by Telesensory Systems of Palo Alto, California. It renders the shapes of letters as vibrating patterns under a finger. The skill required is equivalent to learning a new language. It is most useful for meeting small-quantity reading needs since typical speeds range in words per minute from 10 to 40 with exceptional users reading at 80.

The second reading aid is the Kurzweil Reading Machine made by Kurzweil Computer Products of Cambridge, Massachusetts. It's an automatic scanner, a mini computer for identifying characters and a speech output. Several hundred have been sold, mostly to institutions. It is easier to use - seventy hours of work will make you a skilled user and the effective reading rate on quality print in simple format is about 125 words per minute. Of course, the speech goes faster. Recent hardware and software changes make the speech more "cosmetic" and the controls more "friendly". It handles a wide range of type styles, but efficiency drops fast with quality and complexity of format. Our study of typical print samples found it effective for 25 to 30 percent of print coming across an average desk. At a cost of $30,000, I do not recommend it for individuals. I might change my opinion if two additions were made. As it is, the only other uses one can make of that costly machine are as a scientific calculator and as a speech-output device. Many of us need a personal computer especially for word processing as much as we need a reading machine. We should not have to spent $3,000 more to get it since the Kurzweil Machine has a powerful computer. The second addition is the ability to examine letter shapes as with the Optacon without removing the page from the scanner. This hand scanning option would increase the percentage of materials that could be effectively read without sighted help. The manufacturer's plan to implement these goals was abandoned.

Recent years have been marked by several other casualties. TSI, the manufacturer of the Optacon, failed to make a talking version for several reasons. They stuck with the original camera too long; they under estimated the size of the task; support was withdrawn; and the recession hit.

The Veteran's Administration's efforts to sponsor design of reading machines came to naugh as far as the marketplace is concerned, thought many contributions in human engineering resulted. Only a few found their way into current designs. Mauch Laboratories was the major contractor. Its talking reading machine, the Cognodictor, went through several models. The last model of their tonal-output machine was called the Stereotoner. That was an elegant design but for two fatal shortcomings. Its circuitry was slow to respond, and it was not coupled with the Optacon. The last project we did at Hines and the Illinois Institute of Technology was to design a tonal

output for the Optacon. Our preliminary tests showed great potential. The users liked the increased fidelity of the system, and they preferred using the tactile and audible outputs together. For the first time, the tonal code for reading showed as much promise as the tactile code. We have eight prototypes with which to test, but so far we can't get the support to finish the job. It may be that many people are cheated out of a valuable reading medium that could be an inexpensive add-on to the Optacon and/or the Kurzweil machine. I have not given up hope, but just now people are desperately clamoring for computer aids, so I have postponed (perhaps permanently) my life's goal of assisting in the development of a tonal output reading machine.

A few people are working with commercial *character recognition machines, mainly the Dest.* They are cheaper than the Kurzweil and limited to specific typewritten fonts but more accurate and faster than the Kurzweil machine.

There is talk and a little action in the direction of marrying a reading device to a microcomputer like the IBM PC or Apple to provide a combination computer aid and reading aid. Typically, the designers are not learning much of the past, so they are using higher technology to make the same mistakes.

Speech Compressors

Speech compression isn't getting the attention it deserves either in development circles or in rehabilitation circles. The need for speed listening should be apparent to those who take seriously our need to be productive and competitive. We all know that humans can listen faster than most of us can speak.

However, as you speed up a voice recording, you get pitch and timbre distortion (the Donald Duck effect) which progressively reduces intelligibility. A speech compressor electronically restores the pitch, but it introduces distortion of its own in the form of "clicks" and "gurgle". Early models like the VSC module from the American Printing House and the Cambridge Model A-5 introduced as much distortion as they removed, so their users reverted to "Donald Ducking". The three competing makers can now make acceptable devices which they install or sell to others who build them into modules or tape machines. They are Lexicon of Waltham, Massachusetts, Variable Speech Control of San Francisco and Am-bi-chron of Lynbrook, New York.

There are two problems. Now that there are acceptable products, there doesn't seem to be the enthusiasm to implement the improvements in quality that developing technology makes possible. My opinion is that as a result of having acceptable but not excellent products, the market among sighted people is small, so the prices are higher. The second problem is that many in the blindness community have been turned off by the marginal quality of the early models and some current inexpensive ones.

There isn't space to review all the current options. The Variable Speech Control Company has three good ones. For half track cassettes, they have the Sound Pacer. For cassettes with the four-track Library of Congress format, they have the Sound Cruncher. They also have modules to connect to talking book players. Their address is 185 Berry Street, Suite 364, San Francisco, California, 94107. Telephone: (415) 495-6100. The Model C-80 talking book cassette players have an Am-bi-chron speech compressor of modest quality which some people find useful. The Carroll Centre of Newton, Massachusetts has devoted an issue of its Aids and Appliances Review to speech compression. I highly recommend it.

I advise those who respect their productivity to keep a good speech compressor at hand along with comfortable headphones to use at will. Use of headphones enables faster listening. The electronics or pitch correcting part of the compressor should be connected or connectable with each machine you use for reading; that is, disks, cassettes or open reels. Of course, those machines must have variable speed controls. Unfortunately, assembling such a work station is beyond the technical abilities of many people. The Tandberg Company of Oslo, Norway is scheduled to market a high-quality cassette machine with a Lexicon compressor that may make the job easier.

Computer Aids

Computers are for blind people a unique opportunity, an ominous threat, and a formidable challenge. The opportunity comes from the capacity of computers to translate. They can translate on the spot, for the user, into speech, braille and large print or any combination thereof. In addition, the same text can be reproduced in print, braille or speech recording at great saving of labour. Sadly, most people do not yet have the tools or skills they need to compete.

The threat is that unless we get efficient computer aids we will continue to lose ground in employment. The typewriter was always a mixed blessing for us, but now a blind person with a typewriter, braille and tape machine is ill-prepared to compete with sighted colleagues. The challenge is that we have hardly begun to devlop software to translate "friendly" screen orientations into meaningful speech, braille and large print. In addition, the devices for producing braille are costly while speech devices are inexpensive but need improvement.

Two "paperless or refreshable" braille devices are being made in the United States. The VersaBraille, made by TSI, priced at $6500 has captured most of the market. Much solid development and a few mistakes have gone into this

production and development. For the most part it is a valuable computer aid. Its forte is that it can be used at three levels. When a user changes levels, he experiences a dramatic rise in utility and a drastic rise in complexity. Level 1 is for taking notes or composing texts in any grade of braille desired. The data are then saved on cassette and read by the user on a 20 character display. At the second level one can use the machine as a terminal for main frame computers or attach peripheral devices to it. These include an ink printer or braille printer, an ASCII keyboard and a speech device. At the third level one uses the VersaBraille as a peripheral to a personal computer.

The Microbrailler at $4850 is made by Triformation Systems Inc. After several years of simultaneous marketing and designing, it is still being marketed and still being designed. Though it offers some valuable features we feel it is not worth the lower price for most applications. Its operating system is highly complex and less efficient than that of the VersaBraille. Capitalization and control characters are poorly handled. The most serious lack is its weaker and less reliable braille display.

For many years the only good hard copy braille (page braille) came from the machines made by Triformation Systems costing around $15,000; now the Thiel Company of Germany offers stiff competition in a better machine at about the same price. These costly machines can be recommended for large scale braille production, but there is a lower priced machine available for individuals and classroom use, although there are still some reliability problems to be solved. It is a Cranmer Modified Perkins Brailler (CMPB) made by Maryland Computer Services, priced at $2750.

Large Print Computers and Terminals

A very welcome recent development is the appearance of several large print computer terminals. We have, as yet, had little experience with them. For the most part their outputs are enlarged characters on CRT screens. When a large print attachment for a computer is well designed it can facilitate the use of that computer as a terminal, and as a word processor and it can facilitate the use of many programs by its low vision user. The Sensory Aids Corporation of New Zealand is building the Viewscan text System. It is portable, consisting of a Viewscan low vision reading aid coupled to an EPSON HX-20 computer. Visualtek of Santa Monica, California, offers the DP-10 which is a peripheral for the Apple computer. They also have a large print device for a Radio Shack TRS-80. Apollo Lasers has a large print terminal which also becomes a memory typewriter when attached to a printer. Other alternatives are now appearing. There are Apple programs to generate moderately large print on a high resolution Apple screen. They require no hardware and they work with many programs including the braille edit word processor.

Moderately large print hard copy can be obtained from ordinary printers. Additionally, Apollo Lasers and Maryland Computer Services offer a printer which generates large print.

Speech Output

Discussing speech output is complex, not only because there are so many alternatives but because many people would benefit from using a combination of speech with braille or print. For those with limited braille skills speech is the best for most jobs. However, if the user has good braille skills, braille or print may be preferred for writing computer programs, and for proofreading text; but speech is often preferred for interacting with computers.

One needs also to choose between three alternatives. Alternative 1) get a special terminal; 2) obtain a special computer; or 3) get an ordinary computer and add special devices and software. With a terminal one can communicate with other equipment but one cannot work alone as with a computer. However, a computer can also be used as a terminal. The simplicity ends there because the braille machine mentioned above combines some features of a computer with those of a terminal.

The talking terminals by contrast are all terminals only. These cost several thousand dollars. There are at least four of them - the Vert sold by TSI, the Cybertalker made by the Cyberon Corporation, Free Scan Speech Terminal made by Triformation Systems Inc., and the Total Talk II by Maryland Computer Services.

Talking Computers

Probably the most successful and costly example of a specially programmed computer is the Information Through Speech (ITS) by Maryland Computer Inc. It costs between $10,000 and $13,000 and is more expensive if braille output is required. It is especially efficient for programming.

A company called Audio Visual Operating Systems (AVOS) of St. Paul, Minn., make and sell a package that consists of either an Osborne or a Zorba computer or a Zorba computer and an Echo GP speech device with special software. This sells for $2950.

Special software for the IBM Computer is now emerging. A company called Solutions by Example of Boston, Mass., has software to make the IBM work with popular speech devices. Ronald Hutchinson of Columbus, Ohio, also has such software. Hutchinson has, as well, a program to make the IBM PC speak with an attachment that emulates the popular IBM 3278 terminal. IBM itself also makes a talking version of its 3278 terminal.

The Apple computer is a favourite of many of

us largely because of the pace-setting software written by David Holladay. Speech is easily added with the ECHO II made by Street Electronics of Carpinteria, Calif. With software by Holladay called Braille Edit, all braille devices are supported as well as speech and large print video. Raised Dot Computing (Holladay) offers software to print graphics in braille, a braille training program, a braille blackboard program, and a mathematics blackboard program. Additional valuable software is sold by Computer Aids of Fort Wayne, Indianna. They have a text editor, a terminal program and a data base program all designed to work with the ECHO Speech. I believe those who have both an Apple and either a VersaBraille or a CMPB are among the most pleased and efficient blind computer users in the world. Additional information and all addresses for the equipment discussed can be obtained from Publications of the Carroll Centre in Boston, Mass.[1]

Conclusion

I would like to see development of a portable data entry device, a less costly talking terminal and improved software generally. However, all developments will do little good unless we encourage agencies to establish computer aids clinics. This should be our highest priority.

Reference

1) Carroll Centre for the Blind,
770 Centre St.,
Newton, Mass. U.S.A. 02158

RESEARCH ON AIDS FOR THE BLIND IN THE UK

J.M. Gill
Brunel University, Uxbridge, Middlesex, England

ABSTRACT - The paper outlines current research on aids for the blind in the UK, and discusses some of the problems of converting prototypes to commercially available aids.

RÉSUMÉ - La présente communication décrit la recherche qui se fait actuellement au Royaume-Uni dans le domaine des appareils d'assistance pour aveugles. On discute de certains problèmes rencontrés pour transformer les prototypes en dispositifs disponibles commercialement.

In Britain the emphasis on research on aids for the blind is on single-handicap totally blind persons either of school age or in employment. However of the estimated 200,000 people in the UK with vision less than 3/60 Snellen, about 80% are over retirement age, and about half have a significant second handicap.

The reasons for the inbalance of the allocation of resources are various but include the desire of some research workers to develop academically-interesting technological aids (possibly to be submitted for a university degree), as well as the relative ease of obtaining funding to develop novel aids for the 'blind elite'. Also this group is more articulate at expressing their unmet needs.

Aids can be grouped by the type of technology involved:

1. Special high technology aids
2. High technology aids relying on existing hardware
3. Medium technology aids
4. Simple aids

The first group includes new electronic mobility aids as well as electronic reading machines. Dr Heyes at Nottingham University has developed a spectacle-mounted ultrasonic mobility aid with binaural output. The audio signal indicates the presence of an object within certain distances; the display is similar to the earlier Nottingham Obstacle Detector.

Mr Fowler at Bristol University has developed a reading aid which gives an enlarged tactual display of the character; this is similar in concept to the Optacon. The main differences between this device and the Optacon are the semi-automatic tracking of the reading head, and the display which is made up of a number of moveable studs mounted on a rotating disc (Fig 1). It is claimed that many blind people prefer this display to that used in the Optacon, but a disadvantage is the physical size of the equipment.

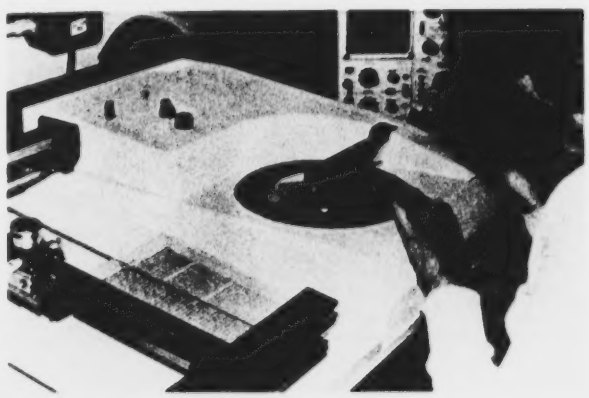

Figure 1 The prototype reading machine developed by Fowler.

A different approach to the design of a reading machine is that adopted by Prof Aleksander at Brunel University who has developed a reading machine with a hand-held camera, optical character recognition and synthetic speech output. He claims that his device will be significantly cheaper than an Optacon yet have most of the facilities offered by the Kurzweil reading machine.

The major problem with this type of research is the conversion of the laboratory prototype to an available aid at a reasonable cost. This conversion process is very expensive and normally requires substantial grants from external sources such as the government.

Government departments tend to look at potential national, rather than international, sales so are discouraged by the considerable investment required for a relatively small number of sales. In the past electronic mobility aids have not proved very popular in the UK; less than 200 have been sold and most of these have been simple obstacle detectors.

The second group of aids are those which use high technology which has already been developed. These include microcomputer-based braille or speech systems and closed circuit television reading aids for the partially sighted. These aids can be developed for a fraction of the cost of the previous group.

Clarke and Smith Industries Ltd developed, with the financial support of the government, a paperless braille device (Fig 2). This was designed specifically for use by blind programmers, although it has been used by other blind people needing a computer terminal.

Figure 2 Brailink (courtesy Clarke & Smith Industries Ltd)

Many of these aids use existing hardware and the research worker develops special software to permit the equipment to be used by or for the blind. For instance BITS (Braille and Ink-print Text-processing System) is a word-processing system which outputs in ordinary print, large print and contracted braille (Fig 3). In this case, the special software is the program to translate the text file to a good approximation to grade 2 braille; this is not a trivial task since grade 2 braille utilises 190 abbreviations and contractions governed by complex rules of pronunciation and meaning. BITS is being used by a number of organisations including a trade union, a major bank for corresponding with blind customers, an organisation for the deaf-blind, a blind school for preparing class handouts, and local social service organisations.

Figure 3 BITS (courtesy RB Aids for the Blind Ltd)

This is an aid where the high cost can be justified by the service it can provide to a large number of users. Another example is the computer software which has been written to produce large print on a high-speed laser printer; this system is now in daily use for the production of large print statements of account for Lloyds Bank's visually handicapped customers.

A number of systems have been developed to make word processing accessible to blind typists. These systems have braille, speech or tactual and audio outputs. A typical system is BASIS (Braille And Speech Information System) which permits a blind person to input contracted braille and obtain printed output using full word-processing facilities. The algorithm for converting contracted braille to print is as complex as that needed for print to braille translation. Unfortunately all these systems are very expensive, and therefore sales are limited to blind schools and the government for loan to blind individuals in employment.

One of the few high technology aids to sell in significant numbers in the UK is closed circuit television for the partially sighted (Fig 4). There are over 38 models on the market of which six are British (Gill, 1984). Research, in Britain, is largely confined to the commercial producers developing variants on existing models. There have been some follow-up studies on patients using these aids, but no systematic work in the UK on the benefits of training in the use of these devices.

Figure 4 Closed circuit television (courtesy J Heathcoat & Co Ltd)

Somewhat surprisingly there are relatively few medium technology aids for the blind being developed in Britain. What few there are tend to be produced in very small quantities leaving foreign commercial firms to develop and produce aids required in large quantities. An example of a medium technology aid is BEAT (Brunel Electronic Aid to Timing) which was developed for a blind percussion player who could not see the conductor of the orchestra. It utilises the radio transmitter and receiver from a model aeroplane, and a modified behind-the-ear hearing aid. This approach of using existing technology developed for another purpose is essential if aids produced in very small quantities are to be available at a price the end user can afford.

Many research workers forget the importance of simple aids such as cheque templates, large print telephone dials and currency guides (Fig 5).

Figure 5 Currency guide (courtesy Lloyds Bank)

Sometimes the aid is a simple adaptation of a sighted aid. For instance, it only requires some lateral thinking to produce a hydrometer which can be used by a blind winemaker. In this case, the container is filled to overflowing with the wine, then the sighted hydrometer is placed in the wine (Fig 6). A template, marked in braille and large print, measures the distance of the top of the hydrometer from the top of the container.

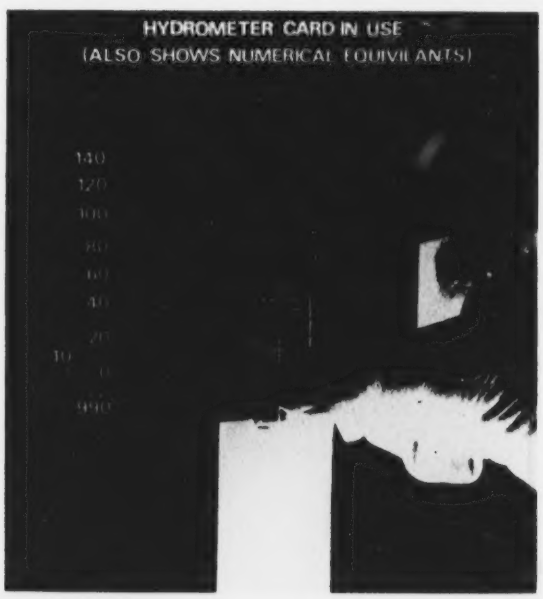

Figure 6 BREW (Brunel Research Equipment for Winemakers)

CONCLUSIONS

To make major advances in reading and mobility aids, more fundamental research is needed on the optimum presentation of non-visual information. Before designing a new mobility aid it would be desirable to know what information is required by a blind traveller and how best to display this information in auditory or tactual form. For instance, it might be possible to pre-process the signal, using pattern recognition techniques, so that the blind traveller is presented with a less complex display which still contains the significant information about the immediate environment.

Research in the UK is done by a number of organisations - commercial, non-profit and charitable. The commercial organisations are understandably interested in maximising profit; this means they tend to concentrate on large volume sale items or specialist aids which have large profit margins. The non-profit organisations, such as universities, are good at undertaking fundamental research and developing prototypes but frequently lack the motivation to convert these prototypes to commercially-available aids. The charitable organisations frequently do not have the expertise to undertake research into high technology aids, but they do have the mechanism for marketing the simple aids.

Therefore a major problem is to coordinate these various types of organisations. The Swedish tackled this problem by setting up Handikappinstitutet which is a government funded organisation for coordinating research, development and production of aids for the handicapped. One benefit was the increased activity on the development of aids for the multiply handicapped. This is a model deserving study by other countries.

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AIDS FOR THE VISUALLY DISABLED IN SWEDEN - DEVELOPMENT AND PROVISION

Dr. Jan-Ingvar Lindström
Swedish Federation of the Visually Handicapped, S-122 88 Enskede, Sweden

ABSTRACT - There is a growing demand from the group of visually disabled people in Sweden to get access to information in the ADL as well as in the job situation. Systems under development are rather complex - not only from the technical point of view. Economic, fiscal and political conditions play important roles.

RÉSUMÉ - Il y a en Suède une demande croissante de la part des déficients visuels d'avoir accès à l'information dans leurs vies de tous les jours aussi bien que dans leurs emplois. Les systèmes actuellement développés sont assez complèxes et non seulement sur le plan technique. Le côté économique, fiscal et politique joue un grand rôle aussi.

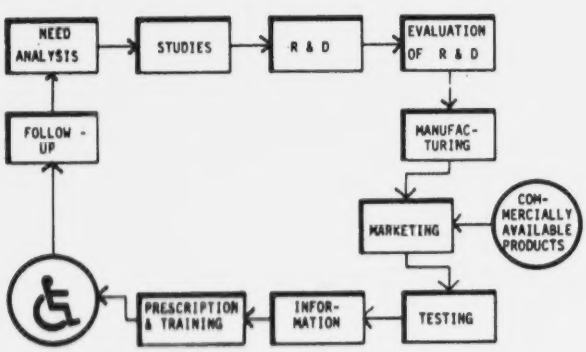
Background

Sweden has a population of about 8,5 million people out of which about 35.000 are known as visually disabled. The total number is perhaps twice as high, but for various reasons those people are not known by rehabilitation authorities.Two thirds of the known, visually disabled are above 65 years of age. Only a small fraction - about 2.000 persons - have no residual vision at all. About 1.500 are considered deafblind, and out of them about 150 have neither residual vision nor hearing.

Aids for daily living as well as for vocational or educational purpose are free of charge and provided at special low vision centres or vocational training centres. Most aids are imported, mainly from the U.S.A and the Federal Republic of Germany, but an increasing number is developed in Sweden.

The process of development and provision

The figure below shows us the closed loop process of development and provision of aids.



The Swedish Institute for the Handicapped - also called the Handicap Institute - has the overall responsibility for the supply of aids, although several independent authorities take part in the process on their own conditions. Thus, need analyses are carried out in close conjunction with the Swedish Federation of the Visually Handicapped, research and development generally paid for by the Swedish Board of Technical Development and carried out at technical universities or in the private industry. Risk capital can be provided by the Handicap Institute both for pilote series and for serial production. Marketing is done by private companies, testing and information by the Handicap Institute and prescription, training etc. by the above mentioned centres for vocational or ADL training under the auspices of the Government or the county councils. Negotiations about prices are carried out by the SUB, a purchasing company founded by the Swedish county councils.

Current trends in development and provision

A visual disability basically causes a communication handicap. In our time, when we rely increasingly upon pictures and text information, there is always the risk that the information gap may increase between the sighted and the visually disabled population. Therefore, it is logical that much effort has been allocated to the development of aids to overcome the information gap.

For almost ten years, a closed circuit TV system - the Magnivision and later the Magnilink - has been developed and manufactured in Sweden. Today, a wide range of accessories can be supplied. In combination with appropriate furniture, it offers the group of low vision clients a versatile tool in the daily living as well as in the job situation.

The biggest efforts are, however, those made to overcome the information problems of those with no useful vision - the blind. Since long, special daily newspapers are edited and recorded with sum-

maries of articles from various papers. However, there has long been a demand for "real newspapers", i.e. recorded versions of newspapers with different approaches and political backgrounds. For about two years, a project has been running where the editorial board has been stimulated to produce recorded versions on C90 cassettes. Of course, these "papers" are much abbreviated but still reflect the content and image. Seven papers are available today.

Recorded newspapers are normally distributed via ordinary mail, but in one case radio distribution with automatic home-recording has been tested. The normal broadcast system is used during a period in the night when no regular transmission takes place.

Abbreviated and recorded versions of daily newspapers represent a big step forward in providing visually disabled people with prompt and important information. However, abbreviated versions will always be considered a poor compromise to those who really want to get detailed information or who have special interests. For that reason, a technically advanced project was started early in 1982, the aim of which is to develop a system where all information could be transferred from the editorial office to the subscriber. A Swedish newspaper, Göteborgsposten (GP), took the initiative and made their digitally stored text information available from the paper's printing house. A transmission and recording system was designed by technicians at the Chalmers University of Technology. The system - now in use on an experimental basis - transmits all text information from the newspaper. The information is retrieved with a special indexing system.

One problem to overcome when digitally encoded information is transmitted, is how to find the proper forms of presentation. In the GP project, the information can be read both on Braille displays and with synthetic speech. A multilingual synthetic speech generator has been developed at the Royal University of Technology in Stockholm and is now being produced under the name of Infovox SA 101 . The Braille displays used are imported from the U.S.A and the Federal Republic of Germany. Besides, two Swedish marks of small Braille printers have just been launched on the market.

Getting access to jobs is an important task for visually disabled people as well as for sighted. Also, much effort is now being put into job adaptations, especially where computers are a part of the working place or can be used to solve problems. For example, work is going on to solve the problems of quick access to dictionaries for a blind translator. Also, Sweden's first blind member of Parliament was elected some months ago, and we are now trying to solve his information problem with the aid of a computer-based system.

Modern technology can both solve problems and create new ones. Telephones are versatile tools for sighted as well as for blind people but appear to be a problem to the deaf and the deafblind. Since a few years, a telephone system based on text communication is established in Sweden for the benefit of the deaf, the hearing-impaired and the deafblind. Texts can be transmitted and received between special key-board terminals. There are also four centres for information transfer, where information can be transmitted from a deaf person's terminal to a hearing person's telephone and vice versa. Deafblind persons are also connected to the system, using Braille displays for the communication.Also, news from Text-TV is transmitted in this way, thus giving the deafblind minority access to a fraction of the news information, broadcast today via radio and television.

The telephone network is also used on an experimental basis to lend a "seeing eye" to the blind. This is done with the aid of telefaximile equipments so that blind people can transmit texts and pictures on a paper to a centre, where sighted people read or interpret the text or describe the pictures and transmit the information back orally via the telephone.

Remarks

Although technology plays an important part in enhancing the access to information for partially sighted, blind and deafblind persons in Sweden, other facts are just as important. For example, social and psychological effects are important parts of the development work today. Also, in a society increasingly involved in information technology, related aids must be designed and accepted to function in a system on certain technical, economic, fiscal and political conditions. It is therefore increasingly important that the development and provision of aids takes place in close co-operation with relevant authorities in society.

TECHNOLOGICAL CHANGE AND EMPLOYMENT OF BLIND AND VISUALLY IMPAIRED PEOPLE

Frank Schmidt, Program Consultant,
Department of Rehabilitation, CNIB, 1931 Bayview Avenue, Toronto, M4G 4C8

ABSTRACT - The benefits of technological advance will only be realized by a widespread understanding of special needs and concepts - like "adaptive" technology; and by a co-operative, multifaceted effort to eliminate current workplace barriers to the greater application of suitable devices.

RÉSUMÉ - On ne pourra vraiment mettre à profit les progrès de la technologie qu'en faisant en sorte que les besoins et les concepts spéciaux, comme la "technologie de l'adaptation", soient compris de tous; il faut aussi faire un effort de coopération et ce, à plusieurs points de vue, pour éliminer les barrières au travail afin d'accroître les possibilités d'application des dispositifs compensant les handicaps.

I INTRODUCTION: "ADAPTIVE" TECHNOLOGY

While it is widely believed that general technological advancement has and will continue to have great impact upon all of us, it is already known that as technological sophistication proliferates, "sightedness" or its absence becomes less and less a material consideration in a hiring or promotional situation because of spectacular growth in adaptive technology. But as we also know, while this is certainly true, to this point in time it just as certainly has been neither fully nor widely recognized. Our concern then, in any treatment of how technological development will affect blind or visually impaired people in Canada, must attend both to technology in general and to adaptive technology.

Many vaguely understand that technology in general will greatly influence their working world in the future. Most think of this influence with definite misgiving, yet adaptive technology as a field, has opened entire occupational groupings within the last 15 years which were once closed to most blind and visually impaired people. In spite of this activity, devices thus produced are, for many reasons, still not readily available to all those who could benefit from them. Our view is that future development in this field will create adaptive devices of even greater potential positive influence upon the matter of workplace integration. But unless there is a creative coming to terms with resolutions to the current barriers which limit availability of these devices, this potential will remain just that - unrealized.

While many types of "aids" have been developed to help with life-functioning difficulties experienced by blind and visually impaired people, most are based upon one or a combination of three sensory replacements for "normal" vision: something (usually amplified lighting and magnification) to enhance low vision; converting that which is visual into something tactual; or converting the visual into something audible.

Adaptive technology's single most influential contribution in each of these directions, for application in both learning and working settings, is the electronic magnification of print, "paperless" braille, and synthesized speech.

Electronic print magnification uses closed circuit television to enlarge print far beyond the capacity of mechanical optics. Many formats have been developed ranging from units meant to be a permanent part of an individual work station, which enable their user to both read and write; to units small enough to be carried in a briefcase from place to place, which provide only reading capability to their owners.

"Paperless" braille devices use standard high quality audio cassette tape as the storage medium for brailled information, and a plate of moveable pins which present the taped data back to the user in the original brailled format. These devices can be used in this "stand-alone" manner, or as portable computer terminals as well, because of their built-in interface capability.

Synthesized speech devices have moved well past the phase of limited memory and spelled speech, and today have many sorts of applications, some of which include: proof-reading of typed copy; data storage and audio retrieval units; and CRT screen readers.

That the future holds even greater promise though, than any of these which we've seen to date, can easily be recognized in one possible scenario selected from only one of these major technological directions. As computer input devices in general use become responsive to voice command; and as output converts to audible - as well as written or video-format; "intelligent" two-way "voice" interaction will only be a matter of time before being realized. Synthesized speech will thus become the new "norm" in certain highly technical occupations, making "sightedness" or its absence completely immaterial to the performing of duties.

II EFFECTS OF TECHNOLOGICAL CHANGE

Turning then to our areas of chief concern, the impact of overall technological change will probably have greater absolute effect upon blind or visually impaired people, than upon the general population, because the greater proportion of our constituents are still at the periphery of both work and those preparation processes which lead to work. The trends which follow, cited by many observers, will have meaning though for everyone:

1. Technology in the long run will reduce employment in the overall sense, as economic growth will eventually be able to be sustained without concomitant growth in labour force demand.

2. Certain major occupational groupings will undergo radical transformation such as: unskilled, low, and semi-skilled jobs of a labour intensive nature in resources, primary industrial, and manufacturing sectors; administrative, clerical and general office occupations; and certain technical, scientific, and educational professions.

3. Industry, business, and government will begin diverting increasing proportions of current earnings, toward conversion of their presently labour intensive work forces, into work forces of properly trained (albeit fewer) employees, equipped with new forms of machinery. This, coupled with the generally deflated economic climate, will retard short run corporate diversification, and protract current levels of unemployment into the medium term.

4. As job availability therefore becomes scarcer, activities of preparation and selection of prospective employees will become much more intensive than presently. Competition for available positions will be keener and a form of segregation - maybe even elitism - will come to be associated with those who are employed.

These prospects for labour force participants with the kinds of special needs which our constituents have, could be both damaging in the personal sense, and destructive of the collective advances which have been made toward workplace integration; depending in the main upon the degree to which adaptive technological advances are included in or excluded from efforts of transition toward the workplace of the future.

Beneath these overall trends however, general technological advance has the capacity to cause specific occupational dislocation. The expected absolute and relative lowering of demand for unskilled, low, and semi-skilled occupations, particularly in the manufacturing sector will be problematic for some of our constituents. In other areas, which by their very nature once lent themselves readily and specifically to our constituents - darkroom film processing, court recording, and dicta-transcription - automated processing has already eliminated or shrunk demand. In still other circumstances, technology introduces visual elements not previously present (such as Displayphone), requiring adaptive technology to catch up, but creating dislocation until it does. Reactions to the flux thus created will compel many blind and visually impaired people to seek reasonable career alternatives, only to find that many community based preparation processes for work are still poorly equipped to suitably and completely meet their specific programming needs.

This relatively bleak picture is somewhat relieved by what adaptive technology has achieved. Devices mentioned earlier and others have allowed blind and visually impaired people to enter and perform in many of the major occupational groupings. This expansion of occupational potential also gradually led to an increasing labour force participation rate for our constituents. And, in qualitative terms, the devices have greatly enhanced worker satisfaction from many perspectives: duty areas, job functions and work sites need lesser "accommodation" activities; work accuracy, precision, efficiency, and productivity are increased; and the devices themselves blend cosmetically into the job station as does other equipment.

Adaptive technology is not a problem-free panacea however. The more complex the device, the higher its initial cost. In Canada, provincial government authorities charged with assisting disabled people to acquire needed equipment, exercise a widely fluctuating willingness, from one provincial authority to the next, to accept these cost burdens. As well, such governmental assistance rarely extends to costs of maintenance, depreciation (for wear or obsolescence), or upgrading (to allow for job advancement). Additionally, as with most complex electronic equipment, the devices are subject to occasional "down" times during which all benefits cease. Servicing is specialized, costly, and time consuming, because of distances from sources of supply and distribution, since most devices are imported into Canada and sales territories are so large. As well, the sophisticated nature of certain of the devices often requires training and practice in their use prior to reaching proficiency with them. And finally, the major devices frequently are concentrated amongst the larger employers and thus in the larger centres. For those who want work this enforces a migration not always desired, and inadvertently creates centralized special populations, and consequent tendencies toward new sorts of employment "ghettos" and segregation.

III RECOMMENDATIONS

Based on all of the above, four categories of recommendation need attention at this time.

Matters relating to disseminating information

Broadly based campaigns are needed to inform and promote the existence, flexibility, and potential of adaptive technology to all aspects of society, including the community of the blind and visually impaired.

Matters relating to costs

Capital acquisition schemes of private enterprise, aimed toward converting to the workplace of the future, must include adaptive technologies - a minor additional component to the overall. Government assistance programs need to be applied consistently across provincial territories and must allow for more than just cost of acquisition. Both of these points attest to the need for a much more multi-lateral approach toward carrying the cost burden, inclusive of more than just the user. As well, maintenance, continuation, and expansion of specialized services and programs aimed at integrating blind and visually impaired people into both the workplace itself and into preparation processes for the workplace (i.e.... education, vocational exploration and development, and skill training programs), need assistance and support.

Matters relating to training

More accurate and finely tuned predictors of future labour force demand areas are needed. Responding to them must be large scale, workplace-relevant training programs, which are flexible enough to fluctuate with rapidly changing technological conditions, and which take account, in their planning, of adaptive technology and the needs of the visually impaired. Among the special needs, it must be recognized that training in the operation and care of adaptive devices is as essential as the training for intrinsic skills.

Matters relating to monitoring/consulting

Encouragement needs to be given to developing more multi-sensory devices which can completely eliminate the ability/disability border - as in the example of the future of synthesized speech. Advocacy needs to be undertaken to forge more closely together the field of adaptive technology with mainstream technological research and development. And finally, recognition and encouragement needs to be given to the highly specialized expertise needed in the application of adaptive devices to specific job sites.

IV CONCLUSION

Technological developments will continue to influence many aspects of all our lives in the years to come. In order that these reformations proceed with the fullest and broadest social perspective, such that their influences upon people are as benevolent, inspiring, and far-reaching as are their impacts upon data handling and production methodologies; continuing consultative exchange is essential. It is particularly vital to blind and visually impaired people, to assure that this technological reformation does not "inadvertently" erode past gains toward workplace integration, and keeps open the fullest potential that the future will offer.

APPLICATION OF AIDS FOR EMPLOYMENT FIELD EXPERIENCE - "GETTING THE TOOLS TO DO THE JOB"

W.A. Tymchuk, Co-ordinator, Technical Aids and Appliances/Vocational Programs,
CNIB Alberta - N.W.T. Division, Edmonton Service Centre

ABSTRACT - Many blind people are unaware of technical aids that can enable them to effectively perform various tasks. Given that such aids are a necessity today, comprehensive evaluation and demonstration facilities staffed by knowledgeable specialists must become readily available to consumers and employers.

RÉSUMÉ - Un grand nombre de personnes aveugles sont ignorantes des aides techniques qui pourraient leur permettre de vaquer à plusieurs tâches. Prenant pour acquis que ces aides sont indispensables aujourd'hui, des structures de démonstration et d'évaluation complètes, dirigées par des spécialistes de la question, devraient être bientôt accessibles aux clients et aux employeurs.

"Give us the tools and we will do the job" - a popular World War II slogan - aptly describes the dilemma facing many blind and visually impaired people today. The job may be there, but it cannot be done without highly specialized and often extremely expensive technical aids.

Let's take the case of 20-year-old Bill Thompson. After completing high school, Bill wanted to use his research and writing skills to pursue a career in journalism - but he had no work experience.

Through Employment Development Services (EDS) - an Edmonton, Alberta, agency with a mandate to find work experience for blind and visually impaired people - Bill received a 14-week job experience with a small weekly paper. But this placement hinged on his ability to access the paper's micro-computer and enter or withdraw information just as the sighted staff do.

While the VersaBraille Paperless Braille machine could enable Bill to access the micro-computer, the question was: who would provide this $9,000 item?

EDS had the mandate and ability to find the job experience placement, but no funds for needed equipment. The paper - already investing time and resources in providing a job experience situation - felt it was not its responsibility to provide specialized equipment. Federal and provincial government agencies can fund technical aids for actual job placements, but not for work experience placements.

In the end, it was The Canadian National Institute for the Blind (CNIB) - through its Technical Aids and Appliances Assessment Unit - that provided the VersaBraille machine for the duration of the work experience placement.

As a result of his successful work experience placement, Bill secured full-time employment as associate editor of a monthly newspaper dealing with the handicapped community. Again, his job depended upon his ability to be competitive with his sighted counterparts. When he was offered the job, Bill had to assure his new employer that he would bring the necessary equipment with him when he started the following week.

The Canada Employment and Immigration Commission (CEIC) has several programs which provide special equipment for employment. CEIC was interested in Bill's case - until it learned that the newspaper is partially funded by a federal program. Thus, helping Bill would, in essence, have resulted in the government subsidizing itself. Consequently, federal government funding was impossible, and Bill was referred to the provincial government and its Vocational Rehabilitation of Disabled Persons (VRDP) program. VRDP quickly handled the paper work, but it was another month before the paperless braille machine and printer were approved - and then the order was sent to government purchasing for the required tendering process.

Bill discovered that this tendering process would then take an additional 90 days, after which time a decision would be made about what unit would be purchased. The entire process could take five or six months - as has often been the case with aids and appliances required by students and those entering the employment market.

Meanwhile, CNIB assured Bill that - even though the agency had other important plans for its own VersaBraille - he could use it until he had one of his own. Then CNIB wrote to VRDP, encouraging speedy approval of the VersaBraille unit - currently the only such unit able to operate a printer.

CNIB's recommendation was not followed, however, because VRDP had literature about another paperless braille machine that claimed that it too had the capability to operate a printer. The manufacturer later admitted that the current model could not do this, but its updated model - scheduled for three months hence - would be able to. This unknown and unproven model would cost less, so - in spite of protests by Bill and by the CNIB - VRDP officials felt compelled to follow their internal tendering procedures (even though the VersaBraille's would-be competitor was still on the drawing board).

Bill continued using CNIB's VersaBraille machine and printer, knowing that it was needed elsewhere by others and feeling as though he were walking in an employment mine field.

This "case history" points out a number of shortcomings related to procuring the technical aids that can make the difference between a blind person obtaining and maintaining a meaningful job - or not.

Most government funding bodies which have traditionally provided such standard items as typewriters, Perkins braillers and tape recorders often are startled at the high costs of today's sophisticated aids - paperless braillers, closed circuit television readers, various types of computer systems, etc. Indeed, these government funding bodies often refer to such "state of the art" equipment as "luxuries."

To the contrary, this high tech equipment is not a luxury but is a necessity in today's competitive job market. This "necessity-not-a-luxury" philosophy motivated CNIB's Alberta - N.W.T. Division to establish a Technical Aids and Appliances Assessment Unit - the most comprehensive of its kind in Canada - in its recently renovated Division headquarters in Edmonton. The work of this unit is augmented by smaller stocks of technical aids in its Calgary and Lethbridge service centres as well.

Seed money for this assessment unit and its stock of nearly 1,000 technical aids and appliances came from the provincial government's Aids to Daily Living (ADL) program in 1981. Since then, it has been difficult to secure ongoing funding for the unit - despite the evidence that it is serving a worthwhile purpose.

There is a critical need for more assessment units of this type, where visually impaired people can have the opportunity to see how various pieces of equipment work, compare them and have a "hands-on" experience with the items so vital to their lives - at home, at school and at work. These assessment units also provide a unique opportunity for employers and employees (and prospective employees) to evaluate equipment and assess its usefulness in a particular job site.

In conjunction with a network of these evaluation and demonstration centres, we must have people knowledgeable about the operation and benefits, advantages and disadvantages of the ever-growing types of equipment available to blind and visually impaired people.

With the rapid changes in technology today, it is increasingly impossible for a person to keep abreast of the whole spectrum of appropriate aids for the entire disabled community. Instead, we need specialists who know as much as possible about the equipment that meets the needs of a specific group - such as blind and visually impaired persons, hearing impaired people, those in wheelchairs, and so on. In the crucial - and rapidly changing - world of computers, for example, the blind or visually impaired person needs to have a reliable source of information about applicable adaptations to computers: synthesized speech, enlarged terminal readouts, braille input, braille output and a host of other options.

Instead, the visually impaired person or the well-intentioned vocational rehabilitation people are confronted by enthusiastic sales people with glowing reports of how well their equipment performs - and little opportunity to compare the actual features and performance of similar equipment. The well-stocked demonstration area staffed by a knowledgeable, unbiased specialist provides a positive path through the maze created by constantly changing technology and the glowing prose of modern marketing.

In addition to the problems of identifying the best piece of equipment to meet specific needs, the blind or visually impaired person is faced with the challenge of securing funding once he has selected an

appropriate item. A cursory examination reveals numerous funding sources, including:

- federal agencies (such as The Career Access Program, the Federal Department of Veterans Affairs, the Federal Public Service Commission);

- provincial agencies (such at VRDP, Students' Finance Board, Worker's Compensation Board, the Provincial Public Service Commission);

- private foundations;

- private service providers (CNIB, for example);

- service clubs; and

- some understanding and benevolent employers.

Each has its various rules, regulations, ifs, buts and maybes - with the end result often being that the consumer's search for the necessary dollars can be a harrowing experience. When a government agency is involved, the mandatory tendering process can result in delays of up to six months - even for such relatively simple items as braillers and tape recorders. In the interval, the person needing the equipment is at a tremendous disadvantage.

In order to ensure that the blind or visually impaired person has the tools to do the job, we must:

1. Start with the assumption that sophisticated but expensive technical aids are a necessity, not a luxury;

2. Recognize the specialization in the field of technical aids for disabled people, and provide specialists capable of providing meaningful advice based on knowledge and experience rather than heresay or glossy, generalized promotional pieces;

3. Establish a network of evaluation and demonstration centres where people can have hands-on experience with potentially useful equipment;

4. Establish lists of all known funding sources - and guidelines for accessing them - for each area (state, province, etc.);

5. Establish better channels of communication between those involved in research and development of technical aids to avoid duplication of time and effort; and

6. Include technical aids information (names and brief description) in career catalogues and career surveys.

In the case of Bill Thompson, commitment to the over-riding philosophy of the necessity of appropriate technical aids led to an innovative solution to the impasse. Through persistent and positive negotiations with VRDP, CNIB reached an agreement whereby VRDP would provide funding equal to the cost of the less expensive counterpart (under development) of the VersaBraille immediately. CNIB then would find a funding source - a service club or individual, for example - to pay the difference so that Bill Thompson could have the equipment he needed to secure his employment - now rather than six months from now.

Commitment to the philosophy that technical aids are necessities, not luxuries in the 20th century, can result in successful, if unorthodox, solutions to troubling problems.

Bill Thompson, a 20-year old totally blind Edmontonian, uses the VersaBraille system in his work as Associate Editor of a monthly publication of the Alberta Handicapped Communications Society.

CUSTOM DESIGN OF AIDS TO FIT SPECIFIC EMPLOYMENT OPPORTUNITIES

William A. Gerrey
Smith-Kettlewell Institute of Visual Sciences, San Francisco, California 94115

ABSTRACT - From our experience with specific needs, we can divide them into two classes: "physical measurement" (gauge reading) and "identification" (sorting items by color). Expanding our solutions to address more general needs is equally important, and future trends are also discussed.

RÉSUMÉ - D'après notre expérience de la nature des besoins particuliers, nous pouvons diviser ces derniers en deux catégories; ceux relevant de la "mesure physique" (lectures d'un indicateur) et ceux relevant de l'"identification" (classement des articles selon leur couleur). L'application de nos solutions à l'étude de besoins plus généraux est tout aussi important; l'auteur examine également les tendances.

Utilization of research--a mandate of these many rehabilitation engineering centers present--often begins with solving an individual's problem, then expanding this solution to encompass more general needs. For example, electronic test instruments developed by blind hobbyists and engineers are now being used by machinists to guide their lathe carriages and by refrigeration technicians to measure vacuum and fluid pressure. Because of the important role which customized devices play, the process of their inception is worth discussing. Because they often lead to the solution of seemingly unrelated problems, flexibility in design warrants consideration.

We have had a preponderance of requests for measuring instruments to be substituted for visual gauges. During our first year, we built an audible vacuum gauge for a refrigerator repairman, a pressure gauge for a repairman of hydraulic turbines, and an electronic substitute for a machinist's mechanical dial gauge (a sensitive moving-pointer dimensional gauge). These and subsequent projects acquainted us with all manner of transducers (classified as "precision input devices," largely intended as sensors for computers).

As output systems for these instruments, we borrowed techniques from electronics engineers and radio hobbyists; these "outputs" produce tones of various character and often have an associated braille-calibrated dial. In part, these schemes were chosen over voice outputs because of their cost; in many cases, tone outputs are more appropriate for presenting dynamic information. (For instance, a pressure leak can best be presented by a tone with increasing amplitude, while an irregularity in a machined part can best be shown by a tone whose pitch varies accordingly.) In any case, a completed instrument would represent the amalgamation of new sensor technology and traditional output presentation techniques.

An exemplary instrument was our elaborate machinist's "height gauge," a device used for checking dimensions of finished parts in a quality-control setting. A plunger-type gauge transducer (a "linear-variable differential transformer" connected to a spring-loaded plunger which is fitted with an appropriate sensing anvil) was chosen as the precision input device. Mounted in a stand over the gauging table, parts could be passed under the plunger to assess their thickness and uniformity.

Three outputs were included on the height gauge:

(1) A precision potentiometer fitted with a graduated braille dial could be adjusted to cause a null in an audible tone; in this way, the absolute position of the plunger could then be gotten by reading the dial.

(2) Fine movements of the plunger could be sensed by listening for a change in pitch of another tone (a sensitive voltage-controlled oscillator would respond to changes in the transducer's output signal).

(3) Finally, individual high and low tolerances could be set; if the finished piece exceeded a tolerance for thickness, a high-pitched alarm would sound, while if the part were too thin, a low-pitched alarm would sound.

Our expertise in building measuring instruments, something for which Smith-Kettlewell has become well known, is based on a library of engineering materials covering precision input devices (transducers), together with the author's experience in readout systems--going back through many years of adapting hobby and school laboratory equipment. (Mr. J. C. Swail, Chairman of this Special Session, has contributed heavily in the area of auditory and tactile output systems; the author has long been a student of his published designs in the Braille Technical Press covering the years 1953 through 1973.) Besides the instruments we have individually built, we have been able to recommend combinations of sensors with

appropriate commercially available test instruments for cases where visual gauges were inaccessible to the blind.

The author and other staff members have given seminars to rehabilitation counselors on the principles of measurement in order to conquer fears and prejudices about certain jobs and their feasibility. Quite often, a counselor noting a job opening requiring a specific gauge (for example, an engine repair position for which a "dwell meter" might be required) will peruse catalogues in vain in search of an adapted version of the gauge. Not finding the specific instrument, the counselor may pass over this opportunity and seek another position for his client. Whereas the specific gauge may not exist in adapted form, a combination of commercial equipment may often be fitted together to fill the need. Rehabilitation personnel should understand the principles of making adapted measuring instruments--fitting a required input sensor with an appropriate readout system--and counselors should be aware of rehabilitation engineering services to which they can turn for help.

Another main area of concern about which we have received many requests can best be classified as "problems of identification." The question most often advanced is, "Has anyone yet developed a color identifier?" The general problem of identifying colors remains intractable. The job of the rehabilitation engineer is one of ferreting out the true nature of the task--reducing it to scientific detective work--to identify items by other physical properties.

Examples of identification tasks are:

(1) Other than sorting by color, wires can often be identified by size, type of insulation, and by using measuring instruments to ascertain unique electrical characteristics within the equipment.

(2) Rather than sorting by color, passive electronic components can almost always be measured with test instruments (this works only if the component is still good and if measurements are not affected by associated circuitry).

(3) Items and materials of different colors can often be sorted by other physical properties; i.e., weight, magnetic properties, electrical conductivity, and sound and feel.

(4) Chemical changes which often manifest themselves as a color change can sometimes be identified using other techniques of chemistry.

Our first experience with this type of problem came as a question in the usual form, "Has anyone developed a color identifier sensitive enough to detect the colored bands on diodes so as to orient them correctly in an assembly task?" Our solution was to build a jig consisting of a continuity tester ("Audicator" by SFB Products, P.O. Box 385, Wayne, PA 19087) connected to a short length of model railroad track. If a diode were laid on the track so as to be "forward biased" (the colored end nearest the negative rail), the continuity tester would beep.

The object was to line up a trackful of diodes biased in the reverse direction so that the continuity tester would not beep; each diode was laid across the rails, and if a beeping sound was heard, the diode was turned around and lined up with its neighbors. The user then scooped these diodes off the end of the track into a narrow box which preserved their alignment, after which the assembly task could be performed with the pre-aligned units.

During one of our seminars with rehabilitation counselors, one of the participants noted the similarity of this example to identification of materials in a tubing factory. The counselor passed over a job opportunity wherein a client was required to sort tubing into various classes, a job which was traditionally done using color. During the seminar, it occurred to the counselor that the tubing could be tested for conductivity (distinguishing metal from plastic) and perhaps tested for magnetic properties (distinguishing stainless steel from steel), etc. Once again, it is important for rehabilitation personnel to be familiar with principles of alternative techniques, and to have consultants to which their problems can be referred.

Whether the problem is instrumentation or identification, there are those who argue in terms of the many exceptions which do not lend themselves to viable solution. For example, it could be said that in the field of electronics, color coding is so pervasive that a blind person should avoid the field; no one can guarantee that every identification task encountered will be soluble. This attitude, however, directly contradicts the success which good rehabilitation engineering enjoys in solving individual problems--sorting wires by length, orienting diodes by conductivity, etc. By properly defining individual tasks and by instituting job restructuring, many jobs become available which can be performed competitively.

We have seen how techniques which have been used to address individual needs can be applied in more general situations; doing so greatly increases the efficiency of rehabilitation engineering. The obvious examples are with our measuring devices, where various transducers have been combined with a standard repertoire of output systems to make additional devices. Our early circuits were divided into "modules"; these could be selected and put together in various combinations. For example, we made a device for counting parts on an assembly line; it had a force transducer (arranged as a weighing scale) as an input device, and its output was the combination of high- and low-limit tones formerly used in our height gauge. In any case, the flexibility in the original design (making voltage levels compatible) will promote universality.

With the advent of microcomputers, the differences between individual instruments will

become more and more a matter of "software" (programming the device to perform a designed task). The instruments themselves will increasingly resemble each other in physical appearance; connections to input devices and the character of their readouts will be the only visible differences. An example of this is the "Talking Thermometer" by the American Foundation for the Blind; its circuit boards and packaging are used as the attachment for talking calipers, etc.

At Smith-Kettlewell, we have recently acquired a computer "development system" with which we can program and fabricate devices containing microcomputers. Given our experience in expanding specific solutions to address general needs, we have chosen to use a rather flexible microcomputer board as the basis for our projects. It has 46 input-output lines which can be used for interfacing with outside devices, and it has sufficient memory to allow considerable flexibility in programming. (A disadvantage is that this computer board is somewhat larger in size than similar equipment which might be developed to fulfill a very specific need; i.e., talking thermometer, talking clock, etc.)

We anticipate that our role in building customized devices will stay much the same as before. As automotive and appliance repair equipment becomes digital in nature, our microcomputer development will allow us to adapt or to duplicate these instruments accordingly. As identification tasks become more complex, a computer can do much to facilitate a large-scale trial-and-error process (for identifying wires, for sorting parts, etc.).

After having made a specific investment in job placement, many counselors and employees fear the development of new technology which would change the character of the job. It is the author's feeling that, whereas jobs come and go as industrial progress continues, the available options are ever-increasing. The rehabilitation engineer will have the flexibility of computers and improved materials working in his favor; a wider variety of equipment will be at his disposal.

LOW VISION CLINICS - A CANADIAN MODEL

S.W. Rudkin, Director of Rehabilitation
Montreal Association for the Blind, Montreal, Que. H4B 1R3 and Vision Canada Centres, Ottawa, Ont. K2P 1V3

ABSTRACT - This paper describes briefly the evolution of low vision services in North America, the various service delivery systems and the formation of a unique Canadian model: VISION CANADA CENTRES.

RÉSUMÉ - Ce rapport décrit brièvement l'évolution des services de basse vision en Amérique du Nord, les différents services offerts à la clientèle, et la création d'un modèle Canadien unique: LES CENTRES DE VISION CANADA.

If someone were to ask what the most significant advance had been over the past 30-years to help the blind, a variety of answers might be expected. Medical developments, braille, guide dogs, computers, lasers and a host of other subjects might legitimately be cited.

Having worked in the field of blindness for the last 18-years, I too have very definite opinions. In my view, there have been two gigantic developments in work with the blind over the past 30-years which overshadows all others. The first was the development of the simple long cane or Hoover cane, after the second world war, which led to the organized formulation of orientation and mobility training for the visually handicapped. This had tremendous impact on work with the blind for two reasons. First, and most important, it demanded a new attitude from the public, workers for the blind, and the blind themselves.

By its very nature, mobility training highlighted the new attitude that blind persons can be independent and indeed perhaps should make an effort to be as independent as possible.

Along with the creation of standardized mobility training came the graduation of the first university specialists specifically educated to work with the visually impaired. The establishment of university programs at the masters degree level in the mid-1960s to educate these professionals had a profound positive effect on the rehabilitation of the blind and visually handicapped in our society.

LOW VISION

The other significant development which has appeared over the past 15-years has been the explosion of activity in the field of blindness, often referred to as "low-vision." There have been of course, for centuries, medical specialists who have laboured to preserve or restore persons vision either by medical or optical means. Everyone is familiar with the professions of ophthalmology, optometry and optician, who serve the eye-care needs of the general public for most medical and spectacle requirements. The general public who require routine eye-care and correction however do not represent many, who today, would be classified as partially sighted, or having low vision. This new classification has slowly arisen in work with the blind, as advances in visual aids have dramatically increased the majority of legally blind persons ability to see.

The idea or concept that most blind persons can perhaps benefit from low vision aids is tremendously important since it emphasizes the fact that the majority of people who have unfortunately been labelled as blind, can often use their partial sight to advantage. This helps reinforce the expectations that visually handicapped or blind persons can remain or learn to be independent.

What then do we mean when we use terms such as blindness, legal blindness, partially sighted and low vision? How can blind persons see and how much can they see?

It is not the purpose of this paper to discuss this issue in depth but rather to emphasize how the legally blind and partially sighted can benefit from proper low vision care.

The term "blind" in a legal context, is most often represented as being less than 10% vision in one's better eye after correction, or less than 20^{o} of peripheral vision. This means that a person is often referred to as blind if they have any degree of vision from "nil" or "totally blind" at one extreme or up to 10% vision at the other extreme.

To the average person or medical specialist in eye-care, anyone having less than 10% of normal vision would seem to be profoundly limited in what they could likely be able to do visually. Yet, for teachers and rehabilitation specialists working with the blind, even 1% vision can sometimes be used to advantage.

When Sam Genensky in California, modified a closed circuit television system in the 1960s to magnify print and project it on a television screen, he started, in my estimation, the beginning of the low vision revolution.

Suddenly, hundreds, then thousands of legally blind persons, with a little vision, were able to see print using a CCTV. These devices had the capacity of magnifying print up to 65 times, while being able to control contrast, brightness, background and even the choice of black or white characters. The primary disadvantage of these aids were their lack of portability and cost - over $2,000 U.S.

Almost immediately however, blind persons were interested in seeing CCTVs and would usually inquire from their local agency for the blind. The agencies after acquiring such a device for demonstration, quickly discovered clients wanted to see other low vision aids, as well as possible alternatives to the expensive CCTV. It was this demand by clients that led to the development of some of the most effective and comprehensive low vision clinics in North America, located quite naturally within agencies for the blind.

The clinic, attached to the New York Association for the Blind, known as the Lighthouse, is one of many excellent agency run low vision services in the United States. It has served as a model and inspiration for one of Canada's most comprehensive low vision clinics at the Montreal Association for the Blind.

TYPES OF LOW VISION SERVICES

The current interest in low vision and the resulting national publicity in newspaper and journal articles, radio and television, as evidenced by programs, such as the Fifth Estate, have accelerated even further the number of professionals and para-professionals, involved in some aspect of low vision.

Ophthalmology

In Canada, at this time, there are numerous varieties of facilities and services which may label themselves a low vision clinic. Perhaps the most common form is found in some city hospitals. These usually consist of specific ophthalmologists within the hospital who see cases of low vision a half or perhaps one day a week. Other ophthalmologists within a hospital refer appropriate patients with very low vision to their colleague who is more knowledgeable than they in this specialty. The hospital low vision clinic generally has a modest assortment of trial lenses and magnifiers which are tried with the patient.

Unfortunately, most such clinics do not have the aids available for loan or sale, which often results in the patient not ever acquiring the aid or even worse, purchasing a recommended aid from a store, apothecary or opticians and then discovering that they cannot use it effectively.

It should be noted that three essential characteristics of an effective low vision clinic are:

1. An inventory of aids for trial loan.
2. A stock of aids for immediate sale.
3. Thorough training in the use of the aid.

The hospital model despite the expertise and experience of the examining ophthalmologist in low vision usually fails to provide the other characteristics which leads to efficient low vision service.

Optometry

Another profession which is frequently involved in low vision, is optometry. As with ophthalmologists however, few optometrists can afford to spend much of their practice in the extremely time consuming sub specialty of low vision. Optometrists in general are becoming increasingly aware of the contribution they can make in the field of low vision and as in the case of ophthamologists, some optometrists have specialized in this area.

Many clinics now include optometry as part of their examining team and some well known low vision clinics are primarily staffed with optometrists.

In Canada, the two schools of optometry, Montreal and Waterloo, both include low vision as an important part of their curriculum. The University of Montreal send their optometry students on a regular basis for observation and field placement to the Montreal Association for the Blind low vision clinic.

The University of Waterloo has a very efficient optometric clinic at their school of optometry, which includes low vision. Recently, the optometrists in Ontario, established the optometric institute of Toronto which includes low vision among their many services.

Optometric low vision clinics are especially strong in their ability to devise specialized head-borne devices and glasses which may benefit a patient. Unfortunately, the number of low vision patients that can ideally be prescribed head-borne devices is usually less than 10%.

Optician

The optician is another professional who is frequently involved in helping low vision patients. Almost all opticians facilities have modest supplies of magnifiers, binoculars, telescopes and similar aids that frequently benefit persons with low vision. Some opticians have specialized even more in the low vision area and sometimes call their service a clinic.

Consumers

Besides the ophthalmologists, the optometrists and opticians who, as described, have a partial interest in low vision, other professionals and groups have frequently even more legitimate claim to be primarily concerned with this field. Take for example a consumer group of low vision patients, all of whom have low vision, such as the Low Vision Association of Ontario. It has as one of its objectives to promote the development of proper low vision services and facilities throughout the province. Occasionally, an individual who has a personal interest in low vision, perhaps because they themselves or a member of their family are legally blind, make a significant contribution to the field. Mr. Sam Baker in Toronto is just such an example. Legally blind himself and not helped by any of the so called specialists, he discovered low vision aids himself and has endeavoured ever since through his Baker Foundation to supply immediate low vision aids and help to anyone requesting it. The Baker Foundation in Toronto does not use any medical specialists but have through trial and error, a good assortment of aids, and staff that spends the necessary time with the client, continues to benefit many persons with poor vision.

Agencies

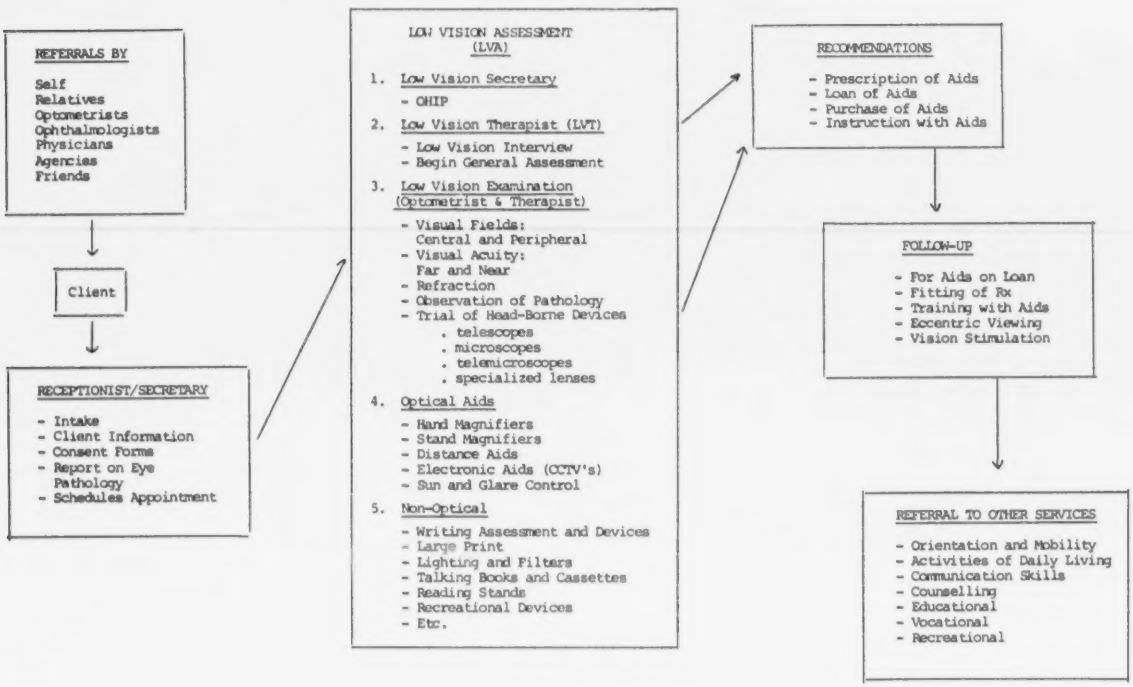
In addition to those already mentioned, another major contributor assisting persons with low vision, of course are agencies for the blind. It is no accident that many of the most comprehensive low vision clinics in North America are operated by agencies. The explanation is simple. Whereas since usually less than 1% of the patients who go to ophtholmologists, optometrists and opticians would be considered low vision cases, almost 100% of the clients receiving services from an agency for the blind have either no vision or low vision. 80% - 90% of persons receiving services from an agency for the blind, have some functional vision. It is natural then that such agencies provide low vision services. The agency low vision service or clinic has many advantages over the other clinic models. First, almost all the clients are low vision candidates. Second, the professional staff are all specialists working with the blind and partially sighted and are able to provide the relevant training and peripheral resources that make the low vision service especially effective. These services normally include orientation and mobility training, activities of daily living and communication skills.

The low vision clinic at the Montreal Association for the Blind is an example of a successful agency clinic that has been a model for two other Quebec government centre clinics and in December 1983 helped establish in our nation's capital, Ottawa, a new low vision clinic that we hope will be a worthy model for the rest of our country.

VISION CANADA CENTRES

This new clinic, we call, "Vision Canada Centres." Vision Canada Centres is an attempt to combine all the better qualities of all the low vision services in our country into the most effective low vision clinic model available and which we hope will serve as an example to the rest of the country, where low vision care is so desperately needed. Vision Canada Centres is both a comprehensive low vision clinic and a rehabilitation service for the partially sighted. Its clinical staff includes: optometrists and low vision therapists who have a variety of professional backgrounds, most conducive to working with the blind and partially sighted. Our low vision therapists include: a nurse, an occupational therapist and a peripatologist, all of whom have extensive experience in working with the legally blind. Vision Canada Centres has an extensive inventory of optical, non-optical, mechanical, and electronic aids, most of which are available for immediate loan and sale at the lowest possible price. Our staff are able to provide training, follow-up and referral to other relevant resources. Our ability to combine the expertise of ophthalmologists in the referral process with those of the optometrists and low vision therapists, have we feel, produced the finest low vision clinic model available today. The schematic diagram outlines briefly the referral process, examination and services at Vision Canada Centres

VISION CANADA CENTRES - LOW VISION CLINIC AND REHABILITATION SERVICE



SPECIAL SESSION/SÉANCE SPÉCIALE 10

ADAPTIVE AIDS/

AIDES ADAPTATIVES

Chairperson/Présidente:

E. Trefler
University of Tennessee, REP
Memphis, U.S.A.

QUESTIONABLE DEVICES

Alexandra Enders, OTR
Tools for Living in the Community, P.O. Box 9989, Berkeley, CA 94709

ABSTRACT - This paper presents an overview of the factors that are involved with the functional use of technology by persons with disabilities. It emphasizes the practical aspects of the provision of technical aids.

RÉSUMÉ - Cette communication examine les facteurs entrant en jeu dans une utilisation fonctionnelle de la technologie par les handicapés. Elle met l'accent sur le côté pratique de la fourniture d'aides techniques.

INTRODUCTION

We all use "technical aids". With the advance of technology, physical strength and ability has declined as the primary measure of worth and the only means to compete for survival. When we need to accomplish a task beyond our physical capabilities, a tool is developed to make that task possible or safer or faster or just easier and more convenient. One of the identifying features of the human species has been its skill at making and using tools. The story of humankind can readily be told as the history of the development of technological innovation.

With tools, we have been able to do marvelous things, things that once would have been considered impossible, or supernatural -- we can poke holes through sliced logs (drill); see through brick walls (window); create fire on demand (match); travel straight up through a building (elevator); fly through the air (hang glider); talk to someone who isn't here (telephone); cut or move things with a lightbeam (laser); make the heart beat when we want it to (pacemaker); walk without legs (prostheses); talk without a voice (communication aid with synthetic speech).

In our society today, there are 'tools' for almost everything, from whipping an egg white to putting men on the moon. Technological development is accelerating at an unprecedented rate. Yet there are many questions unanswered about the distribution, the effectiveness, the necessity of some of our wondrous new 'technology'. Not everyone has equal access to all the tools he or she might want or need, but everyone, in all cultures, feels the impact of technology, or the lack thereof.

Compared to the enormous power of machinery, all human beings are physically limited. At each point in history, society defines and redefines the criteria for physical and mental normalcy. Certain members are excluded from being able to independently maintain themselves based on these arbitrary limits. In cases where technology is able to acceptably compensate for the limitation, especially when a significant portion of the population has a similar disability, the limitation is redefined as being within normal limits, and those people are no longer stigmatized as being handicapped. Disability is a matter of degree. Technology can reduce the gap, as in the case of eyeglasses. Not even airline personnel are discriminated against any longer for wearing corrective lenses, and men do "make passes at girls who wear glasses". Lower back problems seem to be headed into the "normal" range -- there is a store in Boston specializing in low back problems, and it is definitely not focusing its marketing strategy toward the "disability" market; its target is the "normal" person with a back problem. Hearing aids also appear to be heading out of the "adaptive aid" category; even the U.S. President now openly wears one, and the advertising campaigns for hearing aids are increasingly emphasizing convenience, happiness, and quality of life.

The last ten years have been exciting times in the field of applied technology for handicapped people. From a time when there were very few devices, we now have a situation where there are more devices than anyone can keep track of without the help of a computer. R&D efforts have increased; service delivery is beginning to change from an art to a science; and we can begin to exchange ideas about how and why we have succeeded and failed.

INDEPENDENT LIVING MOVEMENT

The majority of disabled people are capable of living and enjoying independent, productive lives. It is not their disabilities that prevent participation in the community, but rather the barriers they face in the home, community, and workplace. Aids and devices can remove many of these barriers.

Probably the single most important factor for the increased attention given rehabilitation equipment in the U.S. is the consumer-based Independent

Living movement, with Federal legislation supporting equal opportunity for disabled persons and equal education for disabled children. These developments have brought disabled people visibly out into the community. It's rare to go to a shopping mall and not see at least one person in a wheelchair, an unusual sight ten years ago. With curb cuts, handicapped parking spaces, accessible bathrooms, etc., disabled people have access to the community. Though demographics are at best speculative, this conservatively estimated 10% of the population is also showing itself to be a "market segment" beyond just rehabilitation-related products.

Technological advances helped motivate the independent living movement by promising more options, and the more active community-based disabled consumer is now creating

(1) a more widely recognized market for equipment.
(2) societal impetus for change.
(3) ideas for technological innovation.

TOOLS FOR LIVING

The dictionary defines "technology" very broadly, to include "the totality of the means employed to provide objects necessary for human sustenance and comfort."

In this session, however, I'd like to limit our discussion to what we can call "Tools for Living" -- that way we'll eliminate the medical devices such as CAT scans, the injury prevention schemes, the emergency rescue devices, surgical implants, etc., and can concentrate on those types of technology that most of us encounter regularly -- the "tools" we use at home, at work, at play, at school, shopping, driving; in all the regular activities of daily life.

I also want to re-emphasize that we all use technical aids -- tools for living -- and that the different between "ours" (the able-bodied's) and "theirs" (the disabled person's) is only a matter of the degree of the limitation being addressed. One question I hope we will all apply to every piece of equipment we use, build, prescribe, recommend for a disabled individual is: "Would I want this piece of equipment in my house, my office, my car?" And if we can't honestly answer "yes", then recognize that it's time to go back to the drawing board or the file cabinet and look for another solution.

Despite the fact that we all rely heavily on tools, when technology is applied to the needs of a person with a physical disability, we somehow find ourselves with a new category of applied technology: "adaptive aids", "technical aids for the handicapped", "assistive devices". These devices are applied to the same range of human activities as are our other tools. The only difference is that they may need to address a larger or more varied degree of limitation. That does not seem a valid reason to treat them as a special category of tool, or to judge their performance by new or different criteria than those we apply to our other tools. What turns a tool into an "assistive device"? Generally, it has the following negative characteristics:

How to Recognize an "Adaptive Aid"

- Stigma attached -- Using one identifies you as part of a "deviant" segment of society.
- Ugly -- It looks utilitarian, institutional, unfinished, or has a Frankenstein image.
- Expensive -- The low market volume and reimbursement procedures force costs up.
- Obvious -- The difference is a noticeable one.
- Lack of status.

The options that technology has opened for disabled people are remarkable. When I see a severely disabled young adult zipping down a busy Berkeley street in a powerful electric wheelchair, alone, independent, in a hurry to get where she is going, I marvel at the advances that disabled people, society and technology have made. But when I objectively view that wheelchair, I lament the archaic ugly pile of wheels and wires that costs almost as much as a small car, and draws a stranger's attention to the device rather than the rider. If the device must be noticed first, then notice the wheelchair in the way you'd notice a fancy sportscar entering a lot -- with admiration, not pity.

Technology has come a long way; it has far to go. We can make it work for us, if we listen to each other and have vision and imagination. The standard that I would like to see used is the main character from the movie "Whose Life Is It Anyway" -- a sculptor who became a high-level spinal cord injury quadriplegic in a car accident. He sues for and wins the right do die. I wonder -- if we had been able to provide him with technical aids that allowed control of his environment, re-entry into his life's work, movement and options for quality of life, with aesthetic style and sense of humor -- would he still have opted to die? Perhaps. But we don't have the technology yet that would have met his minimum standards, and he would have rejected the best we could now offer, with biting sarcasm. This is a character whose needs we should be striving to meet.

We must meet an additional challenge here. There is an unspoken truism that funding agencies won't pay for anything that doesn't have those characteristics of adaptive aids listed above. If a child's aid looks too much like a toy, it won't be funded. If an in-home aid looks desirable or useful to an able-bodied person, or like a luxury or a convenience for anyone, funding will be denied. How can we remove the stigma from tools for living, while retaining necessary funding sources?

SELECTING THE CORRECT DEVICE

One of the prime factors in facilitating the functional use of technology by persons with disabilities is the original selection of the correct device. Because "tools for living" can include everything from getting a replacement crutch tip at a well-stocked drugstore to the evaluation, fabrication and provision of an elaborate customized powered wheelchair system with on-board respirator equipment and environmental control capacity at a special rehabilitation engineering center, we are faced with developing a wide range of approaches to selection, fitting, and follow-up if we are to address the functional equipment needs of all disabled people who could benefit from technical aids.

When categorized according to the level of intervention required, there are three major groups of consumers who use adaptive aids.

Level 1

Most people seeking technical aids fall into this category. They basically need information about what is available, and where to get both the information and the device. They tend not to be connected into the rehabilitation system, nor have they any ongoing need to be. If there were a "Consumers Reports" type publication which could lay out the device features, comment on each, and let the consumers decide the trade-offs, it would adequately meet this group's needs. Mass market media coverage like the November '83 Changing Times article "Things That Help The Handicapped Help Themselves" help steer this group to existing specialized information systems like AbleData and Accent on Information, while reminding them to seek help from local public libraries, and to look for local chapters, organizations, and societies such as the Arthritis Foundation, the Easter Seal Society, or the United Cerebral Palsy Association, in the yellow pages of the phone book. Because rehabilitation professionals rarely interact with this group, we tend to forget they exist. Their equipment needs are often simple and straightforward, which must make their search through our "turf" all the more frustrating. This group also includes the elderly who need to compensate for gradually decreasing physical capacity. It is unlikely that anyone reading this paper fits into this relatively naive category anymore, yet it is important to remember to include the needs of this very large and expanding group in our research and development, program planning, outreach, and information dissemination efforts.

Level II

This group generally uses standard rehabilitation-related products, they may use the rehabilitation system from time to time, and they generally have an idea of where to go to get the equipment they need. They may be receiving occasional services from an Independent Living Center or other established program, and they know how to use the equipment experience of other consumers to help get their needs met. They would look to the professional for help in the selection process, to expedite delivery time, and perhaps for training in use of the device. A competent DME (durable medical equipment) dealership can often provide this level of service on its own or in conjunction with referrals to and from a local therapy department.

Level III

The third category involves the fewest number of customers, but the greatest amount of intervention. These clients tend to be more severely disabled, have more complicated equipment needs, have a larger number of service systems and professionals involved, and generally require a total team approach, thorough evaluation, customized fabricated equipment, training in use of the devices, a shakedown trial use period, and follow-up. These cases are often expensive, time-consuming, frustrating for everyone involved, and very rewarding. It is from this small group of individuals that we are learning the art of technology service delivery. This is where we most obviously see the successes and failures of the tools for living, see how far we've come and how much further we have to go. This is where we learn what questions to ask, and how, when and where to ask them.

The roles of the device provider and of the device user change as we move through these different levels. Moving from Level I to Level III, consumer control decreases as the devices become

1) more expensive: The artificiality of the market appears. When a third-party funding agency or government agency enters the picture, there also comes the increased need for prescription, justification, authorization, and professional involvement.

2) more customized: More professionals become involved in the evaluation, design, and fabrication.

Additionally, the balance of user initiative, payment, and choice decreases as we move from Level I to III. Because the consumer loses direct control as intervention increases, it is important to remember that:

"Active participation in decision-making by clients and families is important to acceptance and successful use of equipment. Professionals must learn to listen and encourage family participation and deal with emotional aspects of client involvement in device selection. Whenever possible, the client should be offered a variety of options. He or she may understand better than the evaluator which alternative is best for his or her living situation." (7)

COMMON CRITERIA FOR A USEFUL TOOL

If it is to be effective, any tool must succeed on two counts:

1) Technical Features
   Does it work?
   Is it strong and safe?
   Is it compatible with other equipment?
   Is it reliable?
   Is it durable?

2) Ergonomic (Human Factors) Features
   Is there a feeling of security when using it?
   Is it simple to use?
   Is it the correct size?
   Is it comfortable?
   Is it aesthetically appealing?

The technical features can be objectively measured; the ergonomic features are more subjective, and should be evaluated in relationship to the device user and/or caregiver. If your overweight, arthritic grandmother does not feel secure on her elevated toilet seat, she probably won't use it; and if you find her bathtub bench a hassle to use with her, it is unlikely that either piece of equipment will stay in the bathroom very long. Based on surveys in the United States (5) and England (6), adaptive equipment often does not measure up very well to these standard criteria for useful tools. Tools that are not useful generally end up not being used.

QUESTIONABLE DEVICES

Because aids and devices hold so much potential for influencing the independence and lifestyle of disabled people, we may need to go beyond the usual questions for judging device effectiveness. Questions about needs, goals, and expectations must be addressed. An unused device can as often be the result of misunderstood assumptions as of technical or ergonomic failure.

It is now time to use the questions we've learned from our clients, from what has worked and from what has failed, in order to get at underlying assumptions in selection, provision, and use of devices, and to start thinking about ways to most successfully integrate appropriate, satisfactory equipment into the everyday lives of disabled consumers. I think we'll discover that we have some very "questionable devices".

The remainder of this paper will be a series of question clusters, aimed at exploring the factors involved in using the tools for living. If you happen to find a few that you could apply outside the realm of "adaptive aids", please feel free to take them with you to your car repair shop, department store, or computer specialty shop, or wherever it is that you turn into a consumer.

- What do you hope to accomplish with this device? Is this a realistic expectation? In whose opinion?

- Do goals coincide with what can realistically be accomplished? mechanically? financially?

- What are the acceptable risks? to whom? in whose opinion?

- Who will pay? initially? for repair? for replacement?

- Which schedules/agendas does this device need to fit into?
  IEP? (Individual Education Plan)
  IHP? (Individual Habilitation Plan)
  IWRP? (Individual Written Rehabilitation Plan)
  funding fee schedule?
  caregiver's licensing requirements?
  transportation system guidelines?
  other?

LOOKING FOR THE CONSUMER

- Who is it that wants the consumer to have this device?
  parent?
  user?
  teacher?
  physician?
  other?
  you?

- Why?
  eases management
  increase function
  employment
  education
  recreation
  other

- Whose life is being assisted? In what way?

- Whose life is being made more work?

- Whose needs are you addressing?

- Who is the "consumer"?
  You may be providing a device to a disabled individual, but who are you "selling" it to? the funding agency? the family? the school? the employer?

IDENTIFYING THE CONSUMERS' NEEDS

- What are the consumer's needs? (We'll assume that this is the person with the physical limitation who'll be using the equipment.)

When looking at functional needs to determine if and when a device may be beneficial, you can use standard checklists for daily living activities, vocational, educational, recreational routines. (Samples of checklists can be found in references 3 and 8 listed at the end of this paper.)

Checklists can include questions such as the following:

- What does the individual want or need to do that she/he cannot do at all, or efficiently/effectively?

- What is the general nature of the desired or needed activity in terms of basic life performance areas? (e.g., training, work, homemaking, recreation, ADL, communication, mobility, transportation, two or more of these designations, other)

- What specific activity (or activities) does the individual wish or need to engage in? (e.g., secretarial work, college coursework, cooking, bowling, grooming, speaking, stair climbing, driving, other)

- What specific aspects or components of this activity are impeded? (e.g., reaching, lifting, manipulating small objects, reading, phoning)

- What is (are) the specific functional limitation(s) associated with the conditions that preclude or impede performance? (e.g., lack of finger function, unable to do independent wheelchair transfer, unable to grasp objects, 20/400 vision in better eye, total deafness)

- How do the specific performance demands of the activity interact with the individual's specific functional limitations to create the performance problem? (e.g., unable to dial telephone, unable to transfer to toilet during work hours, unable to squeeze stapler, unable to read small typeface on insurance documents, unable to hear warning signals)

You might consider supplementing any checklist used with the following questions:

- Can the consumer do this task independently everywhere it needs to be done?

- Does the consumer do this task independently?

- If the consumer cannot or do not perform it independently, is he/she satisfied with the way it gets done?, or is there someone who is not satisfied?

- Does the consumer want to change?

- Does someone else want a change?

- What problems is the consumer having with the current system?

- Is someone else having problems with the system?

- What other alternatives have been considered, or what has already tried which has been unworkable?

- What kind of help is wanted or expected? evaluation only, referral to existing/local resources, device development, other?

OPTIONS

People need adequate information to make intelligent decisions when selecting a device. They also need to be told when there are no better devices to choose from, since the available device -- even though inadequate -- may be either the only or the best alternative to meet the individual's needs.

Every device has limitations as well as assets. Frequently, the client must choose functional advantages and sacrifice activities which seem to be of lesser value.

When trade-offs and compromises must be made, the following questions should also be asked:

- Does this device provide optimal access to the tasks, activities, and goals it was intended to accomplish?

- Is this a substitute for optimum because the optimum was not available? was unaffordable? wasn't compatible with the environment?

- If not optimal access, does it provide equal access?

- If not equal access, does it provide any access?

- If not, is there any reason it should not be considered unacceptable?

- What are the short and long term compromises of using less than optimum equipment?

- What are the consequences of using no equipment?

- Is nothing better than the wrong thing?

- If you wait, and don't get the funding, adequate funding may become available later, and/or a better suited device may become available. Is a piece of equipment in the closet for 3 years better than nothing for 1 year and the right thing for 2 years?

- Why do we have such a hard time saying that there is no currently acceptable technical solution?

HOW TO KEEP EQUIPMENT OUT OF THE CLOSET...

There are questions that can be asked before a device is provided that will lessen its chances of ending up in the closet when it's not supposed to be there. These include:

- Would I want this thing in my house?

- Is it worth the effort to use the device?

- How labor-intensive is it to set up, fit, clean, maintain, store?

- What options does the person have if he/she doesn't use this thing?

- What incentive is there to use it?

- What disincentives are there?

- Can you get by with less, reduce the overall number of devices?

- Do you need more?
- Who will do routine maintenance? do repairs?
- Where will it be stored when not in use?

...AND USE IT IN THE COMMUNITY

There is a whole field of questions that relate to the theme "Would I want to use this thing." They will be specifically different for each type of aid, but the general tone is:

- for an eating device: Would I use it in a restaurant?
- for children's equipment: Would I take it to Grandma's? Would I take it to McDonald's? Would I take it to Disneyland?
- for a communication aid: Would I go shopping with it?
- for adapted clothing: Would I wear this?

A NOTE ON TECHNOPHILIA

Technology produces two groups of people -- those who love it (technophiles) and those who don't (technophobes). Some people have a low "gadget tolerance", and don't feel comfortable around sophisticated assistive devices. Questions about gadget tolerance must be asked of the provider, the consumer, and the caregiver. Devices obviously shouldn't be pushed on someone who doesn't like them; they'll end up in the closet. But there is another danger here, that of the "technophile", the person with a high gadget tolerance. Sometimes devices are requested because they are new, innovative, "glittery", not because they are best suited to the individual. Please note that when the question about degree of gadget tolerance is asked, the provider who is asking the question should do some self-examination about this point, and also looks at the motivation of other team members.

IN SUMMARY...

Optimally, there will be several options available. Questions like these can be used to look at the trade-offs and compromises that need to be made. Individuals and teams might decide to tailor a list to their individual setting, and to assign different values to various questions to assist in reaching an objective decision.

This is far from an exhaustive list of factors, but hopefully it will take us a bit beyond our current forms, and at least begin to bring some of our unasked questions and unstated assumptions into the open for discussion.

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ADMINISTRATIVE NETWORK IN THE PROVISION OF TECHNICAL AIDS

J.J.G. Connors, Health Care Consultant
P.O. Box 2378, Tower B, 2300 Yonge Street, Toronto, Ontario Canada M4P 1E4

ABSTRACT - The administrative network plays a dynamic and essential managing, coordinating, facilitating and supporting role through the full range of activities involved in the provision of technical aids.

RÉSUMÉ - Le réseau administratif joue un rôle dynamique et essentiel de gestion de coordination et de soutien pour la gamme complète des activités que comporte la fourniture d'aides techniques.

When I was invited to present this paper, I had no idea of what subject would be addressed by the other speakers participating in this session. In blissful ignorance I anticipated dwelling on the administrative aspects of service delivery. Then the roof fell in and I became aware that the body of subjects had apparently been picked bare and I had to do some very serious dwelling on the skeletal remains.

Administration is, at best, a dry subject. Consequently, I had to set about the process of attempting to resurrect, reconstruct, aid and rehabilitate what seemed a hopeless situation. With that determination, I realized I had already taken the first step in a process not unlike that of providing a technical aid, namely needs recognition and assessment. Immediately the administrative network took on life with its initial role of resource allocation and management in support of efforts to facilitate the communication, recognition and assessment of a need for a particular technical aid with a logical priorization of that need.

Once the process is in motion the administrative network faces a continuing challenge of resource development through the short and long term. Here the network comes into play in helping identify, access, provide and manage the financial, personnel and material resources required to research and develop the technological solution to a defined need.

Essential to this function is a current information system which allows the identification of probable sources, access methodologies and applicable controls and restrictions. The network must be in continuing communication with the charitable sector, governments and industry. This is no small task when one considers the size and complexity of each of those sectors.

While the current validity of the original need determination necessarily continues under scrutiny, and while the seemingly endless task of resource development proceeds, the network sets about the process of allocating and managing resources in a variety of patterns ranging from global non-accountable grants to fully accountable, target dated project specific funding under contract. The network must reach important decisions regarding the appropriate flexibility and mobility of funding for each particular purpose and the decisions themselves must remain open to re-evaluation as a project progresses or falters. This requires monitoring, evaluation and an adjustment of resource assignment which must interface with the same process at the research, development and clinical levels. In essence, is value being maximized for the devoted dollars, time and effort?

Typically, the process of providing the device flows through a sequence of identifying the need, coming up with ideas and technologies in a research stage, trying and testing those in the development and prototype stages and then moving the prototype into the clinical trial, manufacture, delivery, maintenance and on-going modification phases. In each case, the resource development aspects are likely to be different as are the resource allocation and management models. Additionally, the administrative network will be concerned with the legal protection and informational, if not financial, marketing of the idea and technology. Further complicating the picture will be the motives underlying the administrative network and its funding sources. This can vary, in total or with a particular stage of development, through a range of charitable not for profit to corporate for profit alternatives.

Once a device has made it to the market stage the administrative network has an important role to play in ensuring that the potential market is aware of the available aid and that the device is available and that its quality and cost are respectively maximized and minimized. Also at the service end of the spectrum is the need for an administrative network that facilitates the identification and matching of client need with the available assistive devices. A simplified process of providing the client with payment options and processes with good maintenance and replacement follow-up are additional important tasks.

Having described some of the administrative network's roles, I would briefly like to alude to its general composition which will vary widely by institution, organization, corporation and government. As 'network' implies, there are many more than one element in the administration of the process that provides technical aids. However, there will be key positions or personalities in the process who may appear to work alone but who themselves will be representative of other networks. They will be representative of medical, professional, para-professional, administrative, scientific, and client networks. This demonstrates that while it may be desirable to minimize non-administrative personnel activities in administrative functions, such involvement is essential at least at the informational and quality control levels. Everyone in the process has some smaller or larger administrative function and is a part of the network. The network is not some clearly defined, separate and removeable model which can be viewed in splendid isolation. It is imbedded and interwoven into the fabric of the total ongoing and ever changing processes of the health care research, development and delivery system of which providing technical aids is but one element.

Historically, it may once have been possible to embody all of the necessary scientific, clinical and administrative skills and knowledge in one person. Today that is no longer possible nor realistically desirable. There are too many resources and there is too much information requiring responsible and responsive management. Consequently, there is no rest for the oft' portrayed wicked administration. Helping manage, support and coordinate the politics, the finances, the personalities, the priorities and the communications is no easy task. The network may be accused of being insufficiently or misinformed, but it is incorrect to suggest that the network is devoted to finding reasons to say no or to allocate less. It is even less correct to suggest that the network is oriented to "no" and "less" mentalities without reason.

As has been said, each of us is a part of the administrative network providing technical aids. We individually have our particular input in what should be a discussive and cooperative effort aimed at meeting client needs as simply, quickly and cost-effectively as possible.

The network is there to serve its clients. To the extent possible, administration should remain streamlined current and cost-effective. This means that computerization to help manage information and resources is essential and generally overdue. It also means that simplification, a clear understanding of system needs and objectives and a great deal more inter-network cooperation is paramount. The latter is critical if wasteful duplication is to be avoided. Therefore, it is past time that parochialism and politics took a back burner so that the best interests of clients, whether researchers, clinicians or patients, might be better addressed. Furthermore, the network needs and should provide mechanisms for client input and feedback. This does not mean a co-opted involvement but a practical constructive role.

My formal presentation has been deliberately general and brief. We are here to exchange ideas in discussion. I have not attempted to talk about the detailed anatomy of any particular administrative network or model. I don't believe any one approach is the best or worst. There are a plethera of approaches within Canada and many more on the international scene. Every network has its peculiar set of determining premises and pressures and responds accordingly. I hope that at least a background has been set for questions about the problems and potentials of our respective networks be they in the voluntary, corporate or government sectors. I hope, also, that we might consider our particular networks in the light of the principles alluded to throughout the past few minutes.

The networks are alive but how well are they? How mired in unnecessary red tape and inflexibility are they? How current, accurate, complete and relevant is their information? How much intra and inter network duplication is there? How cost-effective is the administrative effort? Where, when and how can improvements be made and who is likely to be involved in the task? Collectively we have the answers to all of these questions and the responsibility to work together toward improving or replacing our existing networks.

IMPLICATIONS OF THE ENVIRONMENT FOR PERSONS WITH DISABILITIES

Mrs. Pamela Cluff, FRAIC, FRIBA
Associated Planning Consultants Inc., Toronto, Ontario

ABSTRACT - This paper addresses the barriers and solutions encountered by a variety of disabled persons in the built environment. In particular, it is concerned with a systematic and holistic approach to the identification and removal of barriers through the use of broad technologies utilized in the construction industry. In addition it is suggested that the responsibility for solution generation or adaptiveness should not be the sole responsibility of the disabled individual, but society as a whole, in order that disabled persons can become fully integrated, contributing members of our society.

RÉSUMÉ - Cette communication traite des barrières que rencontrent un grand nombre d'handicapés dans l'environnement "construit" et des solutions à ces problèmes. De façon particulière, elle traite d'une approche plus systématique et plus globale à l'identification et à la suppression des barrières par le recours aux techniques générales utilisées dans l'industrie de la construction. De plus, il est suggéré que la responsabilité de trouver des solutions ou de s'adapter ne revient pas aux seules personnes handicapées, mais à la société dans son ensemble, si l'on veut que les personnes handicapés soient intégrées entièrement et qu'elles deviennent des membres actifs de notre société.

As I consider the issue of 'Technology Impact' in the external environment, as it affects disabled persons it occurs to me first and foremost that an extremely high proportion of all the concern in the past and the subsequent development of solutions has principally been focussed on the needs of the 'mobility impaired' and their encounter with stairs, curbs and public transportation. In addition, the focus of the rehabilitation professionals has been predominantly on those whose life-skills or opportunities, would benefit the most ie: children, young adults and those in the workforce.

As a whole, therefore, the architectural profession, where it has taken notice, has attempted to resolve problems in terms of those priorities. Rarely, if ever, has a holistic approach to 'accessibility' been taken and rarely, if ever, are all disabled groups or individuals, with unique or complex needs, taken into account. And so we find ourselves with an abundance of guidelines and design criteria for wheelchair users, in the form of building codes and standards; an excessive concern with fire-safety for disabled persons and some peripheral information on what to moderate in the physical world to make it suitable for the blind, or the perceptually impaired.

Yet when one looks at the whole population of disabled persons, we find that no one individual will stay in a neatly labelled package of disability, or a prescribed role in life - indeed 'tous ça change' (everything changes). Along life's continuum; the child with cerebral palsy grows up, and may go to work, drive a car, get married and become a parent. The young man who had the diving accident and is a paraplegic, gets re-educated, obtains a job with government, travels frequently by air and also becomes a father and a political force. In another instance an adult disabled person who has been socially active refuses to stay 42 years old for ever, and retires from the workforce with increasing arthritic problems and a mild stroke and is confined to his home where he becomes increasingly frustrated by his narrow social confines; and yet again the mother who developed multiple sclerosis in her early 40's, finds her children leave home in their late teens, and so does her husband, leaving her to cope with an increasingly disabling condition and a lack of caring others.

What we see then are people first, with life-skills and life-needs which are continually changing, and in roles assigned or chosen by them, by society, their families and their work situation. As architects, this life-cycle of activities requires that we understand the developmental variations of disability and the unique roles each person plays in society, and then attempt to resolve those public and private environments in which people live, work and play, have families, friends and sex, in order to ensure that we create, with our technological skills supportive settings which enhance human performance in its many forms, rather than creating and re-creating a systematic series of barriers to their independent activity.

The technology of construction and design is moving ahead as fast as the concept of rehabilitation engineering and its related technologies. Each year some 7,000 new building products and systems hit the market in Canada. Were it not for the economic slow-down this figure would be continuing to expand exponentially as it did in the 60's and 70's, and we would find ourselves falling even more rapidly behind.

Coupled with other constraints, for example the time it takes to design and construct buildings and public settings, with all the contingent delays necessitated by the various 'approvals' processes, we frequently find ourselves being the authors of buildings and facilities which are obsolete before they're put into use, not only in the technological sense, but in the sociological and philosophical sense of the times.

However, let me go back somewhat to my initial thesis. Since we are rarely dealing with

the needs of one specific disabled person at a time, we must conceptualize the potential disabled community as a whole, and identify those unique dilemmas which as a group,or as individuals,they may face, in the settings we create. From our own research we therefore recommend dealing, not with the wheelchair user per se but with:-

- The mobility impaired;not with the blind, but with:
- The sensory impaired,and so on through to and including:
- The co-ordination impaired,
- The strength and endurance impaired;
- The mentally impaired,and
- The situationally impaired.

This latter category defies many listeners as a rule, until we explain that this could include those who are too tall, or too small, too heavy or too obese, those who are pregnant or at a social disadvantage eg: they don't speak the language, or are on heavy medication, or who have had too many drinks.

All of these situations occur in real life and in the physical world, which we have created, not only in specific buildings and places but at the 'interface' with other buildings and systems.

People first and foremost will not stay in one role or setting and insist on growing older at a constant rate. In addition, and increasingly, disabled persons are insisting upon their right to be totally integrated into the mainstream of society and take the same risks as the rest of us. That includes the risk to die in a fire or a plane crash. The physical environment must therefore accommodate those needs, and when simple physical adjustments to design cannot do technology must be utilized whenever possible.

One of the largest underaddressed areas in the physical world with respect to individuals with disabilities and technology, is the area of "aging". As a society, for the first time we are seeing a shift in the dependency ratio ie: by the end of this century there will be more persons over 65 than under 18. In terms of rehabilitation engineering technology, this group is therefore deserving of our specific attention. In addition, for the first time we are experiencing the success of the rehabilitation movement in that many disabled adults are now surviving into old age. The impact of these two phenomena will continue to grow and affect all our concepts of appropriate solutions. In the built environment this will mean more people than ever before with decreased hearing and perceptual skills, decreased strength and stability, decreased manual dexterity and decreased energy. This will require a concomittant increase in environmental responsiveness to these losses, some of which will necessarily derive from fundamental and specific technologies. There will be a greater need therefore to ensure that all communications and information systems in both public and private settings are appropriate for these users, it will mean that the physical world which was designed principally with the young active male adult in mind should instead meet design criteria more appropriate for elderly frail women (who will be the majority). It will mean that walking surfaces, lighting conditions and acoustical treatment or enhancement, will need to be responsive to reduced ambulatory skills, reduced ability to differentiate between surfaces and colours, and complex background noise. It will mean that all analytical and design professionals seeking to enhance independence through the creation of 'prosthetic environments' will have to consider the "empathic" approach as developed by Leon Pastalan, to identify and resolve potential problems.

Even with improved glasses, hearing and walking aids, the elderly will be 'at risk' in an environment designed for the healthy adult. However it is heartening to know that solutions which are appropriate for such elderly persons will benefit all other disabled persons. It is even more heartening, when, unlike the direct prosthesis, one realizes that good responsive environmental design is totally integrated and non visible. This alone ensures a minimum of attitudinal concerns about 'special aids' and related costs and has an added benefit in that it is an extension of 'preventive' concepts, which we will all live to enjoy.

We have just recently completed some research for the Canadian Human Rights Commission attempting to demonstrate to Government departments and agencies what the whole realm of accessibility includes. One of the approaches we utilized was to examine the 'potential' barriers which might be encountered, by each of the generic groupings of disability which we identified. To do this systematically, we had to assume a mythical 'scenario approach' to every potential situation in the physical world. This included approaching, entering, using and leaving private and public buildings for work, recreation, care and service delivery under average and emergency conditions.

It also included the listing of encounters with systems such as public transportation, private transportation, communications systems such as telephone, radio, T.V., news media, cinematography, computers, public address systems, etc., as well as air conditioning, heating and acoustical systems, etc. Further, we attempted to address the human experiences and the encounters which include a multitude of attitudinal and learning barriers.

What became evident during the research was that every system was imperfect under certain conditions, but more critically we became convinced that the need and responsibility for adaptive strategies or mechanisms should not be the sole responsibility of the individual disabled person, ie: one-on-one technology can only go so far.

For instance, we still have transit regulations which will not allow disabled travellers with battery powered wheelchairs to carry these on board planes, except in special containers. We also know that many hearing aids will not work in settings even with FM. loops because other building electrical systems which produce magnetic

fields of interference. In particular we encountered paranoia about fire hazards.

Fire marshals across the country will not allow (if they are aware of it) persons with limited mobility to live alone on the upper floors of apartment buildings. Fortunately, they do not track these hardy individuals on a daily basis, or they would find them in the bar on the top floor of a hotel-in a revolving restaurant, or visiting a friend on another floor, or working in a high-rise downtown.

The responsibility for ensuring that existing and future buildings and/or facilities will allow these ventures into normal life, will remain for the time being with the designers and contractors. What then are the technological capabilities at hand?

The most obvious are those which are an outgrowth of the transportation and electronic and communication systems developed largely as a result of the space programmes of the 1960's; plus the enormous strides taken by the computer industry as the result of the portable micro-chip.

The easiest problems to resolve architecturally are once again the most obvious barriers to the mobility impaired. Level entrances or ramps where there were once steps and stairs, assisted door openers, where once there was a battle with the buildings' air pressure system plus the weight of the door. The controls for lighting and building systems at heights within the reach of the persons in wheelchairs. Door hardware and faucets which can be used with a simple one-armed action, temperature controls on hot water supplies; space for mobility and transfer; wider door openings with no thresholds. We now have this lexicon of solutions for 'mobility' access at hand to which further refinements can be added when the specific disabled individuals' needs are known.

We still however, have done little with overall building systems and related controls. Standards and guidelines are required for lighting levels, the use of colour and appropriate signage, acoustic controls, sound systems, both one and two-way communications, air-quality control including humidification and air conditioning. The technologies exist, but there is generally a reluctance on the part of both public and private sponsors, to support what they perceive to be "extra-ordinary" costs for these so-called refinements.

However, those of you who are disabled, or who work daily alongside them, understand that extra-ordinary costs and individual adaptiveness are already a part of every disabled persons daily life and that such initial costs are nominal when compared with a life-cycle cost approach, ie: of supporting a totally dependent individual in a constrained environment, or recognizing that their contribution to society as an independent individual is of considerable worth.

In the 1960's and 1970's such rational cries were heard in a wilderness. Today the climate of change is ripe for the pursuit of these objectives, and now in Canada for the first time we have a fully supportive document in the Federal Charter of Human Rights, under which every Canadian has the right to expect equable treatment under the law, including equity of opportunity in every situation.

As one of the design professionals committed to ensuring that such opportunities come about, I am happy to share with you some of my experience in the field of design and to learn how emerging technologies might best serve our disabled citizens, I therefore welcome this opportunity of being here at this conference, and this opportunity of talking with you.

PSYCHOSOCIAL ASPECTS ON TECHNICAL AIDS - HOW DOES INDEPENDENT MOTILITY AFFECT THE PSYCHOSOCIAL AND INTELLECTUAL DEVELOPMENT OF CHILDREN WITH PHYSICAL DISABILITIES?

Karin Paulsson and Maria Christoffersen
Handicap Research Group, Karolinska Institute, Stockholm, Sweden

ABSTRACT - The paper reviews a project studying the effects of giving independent mobility in the shape of electrical gocarts to 12 physically disabled preschool children (2 1/2 - 5 years old). According to the results many positive effects on the psychosocial development could be recorded. To prove effects on the intellectual development was difficult because of methodological problems (the number of children was small, external factors could not be held under control etc.). No negative effects on the motor development could be noted, only positive effects. During more than one year only three incidents happened and nobody was hurt by the gocarts.

By tradition habilitation of physically disabled children has been focused on the medical and technical aspects of the physical disability. The main goal was and is still to reduce or compensate for the physical limitations of the child by training, operations and/or technical aids. Too often it is forgotten that children with disabilities are first of all CHILDREN with the same needs and wants as other children.

Today concepts like "total view" and "total habilitation" are in fashion, but how does it work in practice? Even if we have a better knowledge of childrens´s needs today we often are faced with situations when medical demands are (or are thought to be) in conflict with the psychosocial needs of the child. In such situations the medical aspects are always regarded as the most important. Sometimes deeply rooted routines or even human prejudices lead to important parts of the child´s development being neglected.

Professionals usually see technical aids as aids to restore or compensate for a physical function. But technical aids can be much more that that! They can stimulate the intellectual and psychosocial development of children and they can change the whole life situation of the family. There is a lot to be said about this but since half an hour is a very short time I will concentrate on one of our research projects that vividly demonstrates how mobility aids can play an important role socially and psychologically in many different ways. The project is called "How does independent mobility effect the psychosocial and intellectual development of pre-school children with physical disabilities?"

Aims of the study

The aim of the project was to study if independent mobility (in the shape of small electrically driven mobility aids) would influence the social, emotional and cognitive/intellectual development of physically disabled pre-school children (2 1/2 - 5 years old).

Another aim was to analyse if this kind of technical aids could have a negative effect on the children´s motor development and make them less motivated for physical training and physiotherapy.

A third part of the aim was to record all kinds of other risks that could be at hand, for instance the risks of being hurt (either the disabled child itself or other children playing with the disabled child), inability of the children in manoevering safely, traffic risks etc.

Background of the project

The reason why I wanted to do this study were experiences from another project in the early 70´ies. The aim of that study was to follow up the situation of 15 children in the ages 8-11 years who "by mistake" had had electrically wheelchairs for outdoor use prescribed by their doctors. The most important aim was to find out if there could be any risks since Swedish experts on children in traffic had concluded that children below the age of 12 were not mature enough to be in traffic and many physiotherapists argued that children should not use electrical mobility aids so early because then they would be passive and lazy.

What I found was a minimum of risks and a maximum of positive aspects. The most important result was that neither the interviewed physiotherapists nor the teachers and parents thought that the children had become more passive after having their electrical wheelchairs. Instead many of them reported that the children had become more active. Some quotations give a vivid description, "More active now. More of a boy now, less childish" (parent), "On the contrary! She is passive when she is without it. Only lying on the floor, does not want to go out at breaks" (teacher), "It works as medicine for depressions" (physiotherapist), "Better than Valium!" (physiotherapist).

Several of the teachers and physiotherapists related stories about dramatic changes in the children´s lives after the prescription of the electrical wheelchairs. One child who refused to go to school started school again. One boy with a muscular dystrophy had been very depressed and could not stand looking at himself in the mirror. When he got his electrical wheelchair he felt that the strength of the wheelchair was like being strong himself and many of his psychological problems disappeared. Another depressed girl who did not care about herself or the world around her "blossomed and started to curl up her hair among other things". Some teachers also told me that the children had started to read better after the prescription of the mobility aids.

The experiences from this project inspired me to recapitulate what I had learnt about children´s psychosocial and intellectual development. I also went to university libraries to find out more about the effects of restricted mobility on children´s development. I soon realized that, as far as I could see from the references, very little had been done in this field. Then I decided to do a project to test some of my hypotheses based on developmental theories.

Hypotheses and theoretical background

My hypothesis was that the psychosocial as well as the cognitive development of physically disabled children will be facilitated if the children at an early age are supplied with mobility aids that make it possible for them to move about independently without too much physical effort. The mobility aids must be so easy to use that the children´s spontaneous curiosity and joy of exploration is not hampered by the effort to move.

My theoretical base was as follows:

Children´s psychosocial development

In Erik Homburger Erikson´s theory about children´s emotional and social development it is stated that children, at the age of 1 - 2 years, begin to develop a sense of independence and of being a person of their own separated from others, with control of their own bodies and capability to affect the environment. During this period the children´s selfconcept is built up.

Between the ages of 3 - 6 years children start to explore the world outside the family. During this period the development of initiative is the most characteristic. The children have a lot of energy and are always planning new activities. They also start learning to take responsibility for their actions. During this developmental phase it is important for children to play and associate with peers.

My hypothesis was that a physical disability has a retarding effect on this development process. Children with disabilities need much more practical assistance than their peers and most likely this physical dependence makes it more difficult for them to develop a psychological independence. It cannot be easy to maintain your own will, if you need help to do what you want to do, and it cannot be easy to develop initiative if it cannot be followed by immediate action without barriers.

I also assumed that lack of independent mobility would effect the social development, for instance the possibility to play with other children on equal terms, to take simple responsibility in the family, to make new contacts outside the family etc.

My theory then was that if physically disabled children got the opportunity to move about independently their psychosocial development would be stimulated. I also thought that this would give them a higher status among other children since there are studies (Mussen, Conger and Kagan, 1969) showing that children who get a lot of help from grown-ups are not accepted as easily as others by their peers. According to psychological theories by Mead, Piaget, Erikson and many others children develop in an active interrelation with their social environment. This made me believe that a higher status would lead to a higher self-esteem since "What you think of me, I will think of me,
What I think of me, I will be.

Children´s cognitive/intellectual development

"The child learns by doing". All theories concerning intellectual development stress the fact that all human intelligence, even in its highest forms, is based on early sensory - motor experiences. Scientists like Piaget, Bobath, Frostig, Ayres and many others state that children learn about the world by moving around and exploring the environment with their hands and mouths. By picking up objects and putting them in the mouth young children get experiences of size, form, texture etc. By crawling and walking around they learn about concepts like distance, the relative size and form of objects seen from different perspectives etc. Later they learn to recognize things by vision only and to generalize concepts, for instance that a chair can have many different shapes but still be categorized as a chair. These early experiences are basic for the development of a more abstract thinking and for the understanding and handling of abstract symbols as letters and figures.

For children with severe physical disabilities the possibilities to move and to explore the world are highly restricted. Most likely this has an influence on the intellectual development, especially the development of perceptual concepts.

My hypothesis was that the cognitive development would be stimulated by independent mobility since,

"I hear and I forget
I see and I remember
I do and I understand"
(old Chinese proverb).

or expressed in other worlds,

"Nothing becomes real until it is experienced"
(Keats)

Methods

To carry through this project was more difficult than expected! The strongly negative attitude from doctors and physiotherapists towards electrically driven mobility aids for such young children as we planned (2 1/2 - 5 years) forced us to give up the experimental method we had planned to use, involving 20 children in an experimental group and 20 in an control group. After half a year we could only find 12 children in all Sweden for whom the doctors were willing to prescribe either a BEC-Bambino (a small electrical wheelchair) or the specially constructed electrical gocart that was made as part of the project. The main argument was, "The children will be lazy and unmotivated for physical training". Other common arguments were,

- "Too big risks for accidents"
- "Such small children will not be able to learn to drive"
- "Gocart is not on the list" (the list of technical aids that are tested and approved of by Swedish Handicap institute. Since there was no gocart in the market it could not be on the list)
- "You cannot give so expensive toys to children"

Faced with these difficulties and the methodological problems they caused I wondered if it would be meaningful to do a project at all. But since I had not found anybody else working with these to me very important questions I decided that even a project based on relatively simple methods without scientific exactness and stringency would give some valuable information.

So we chose to make a follow-up study based on our 12 children. Their diagnoses were: spina bifida (6 children), congenital injury of the spine (1), muscular atrophy (1), congenital amputations of arms and legs (2) and cerebral palsy (2).

Eights months before the delivery of the mobility aids to the children, immediately before the delivery and one year afterwards the children´s intellectual ability was tested by phychological tests and their motor development and physical function was evaluated by their physiotherapists. On the same occasions parents, physiotherapists and pre-school teachers were interviewed. The physiotherapists were also asked to make regular controls of the children´s motoric function. By these controls we could check up any signs of motoric regression that would cause us to stop the project. In addition to this the children were filmed the first time they tried to drive the vehicles and one year later.

Some results from the project

Effects on the phychosocial development

For all children but one big changes in their emotional and social development could be recorded during the one year follow-up study. For some of the children these changes were dramatic. The most important effect according to the parents was the children´s increased self-confidence and their physical and psychological independence. "Not until now has the umbilical cord been cut" as one mother described it. The ability to drive away alone when they wanted and to whom they wanted was a new experience for the children. Earlier they had to sit at home waiting for others to take the initiative to contacts.

The relationship to other children was also changed. The disabled children aquired a higher status position among their peers when they drove along in their motor vehicles which for a long time attracted lots of attention in the whole neighbourhood. The children now could play together with their peers without needing assistance from the parents all the time. By competing with other children on tricycles and by threatening to "drive over" anybody who was not fair to them (they never did so in practice) their status was even more increased. As an example it can be mentioned that when the children were playing family games the disabled child now was allowed to have some of the active grown-up parts instead of being the baby or the dog as before.

Some of the children also started to test their will against the parents and siblings. They became obstructive, teasing, rude and difficult to handle in many other ways just as other children usually are at certain ages. After some time this behavior decreased to a normal level.

Many parents described that before the children got their gocarts the mothers had to carry the child to the sandbox where it could sit playing for a while with the other children. But when the others got bored of the sand and drove away on their tricycles the disabled child was left behind in the sand, often crying. Most of the parents mentioned that the risk of overprotection was overwhelming in situations like those. According to the parents this risk became much smaller after the children got their gocarts because then they could manage quite well without assistance and the relationships to the peers improved very much. Several mothers also mentioned that it was a great relief to themselves, psychologically and physically, to see that the child was able to play alone or with other children for short whiles. Then the mothers could concentrate better on the household work without having to run outdoors every fifth minute to help the child.

It is interesting to note that although many of the children were rather mobile indoors (our initial ambition to choose only severely disabled children had failed by the above

mentioned methodological problems) they had great difficulties outdoors before they got their electrical gocarts. Indoors they could shuffle, roll, walk on their buttocks or use a simple mobility aid. For outdoor use most of them had hand-manoevered tricycles or other mobility aids but these could only be used on flat, even and hard surfaces like asphalt. Most of the time the children were passively pushed in a stroller or some kind of cart. Both parents and pre-school teachers related that, because of the big outdoor problems the children preferred to stay indoors. When outdoors they were often not allowed to take part in the games of other children and some of them showed clear signs of regression in these situations. They became whiny , "childish" and clung on to the preschool-teachers. A few children tried to maintain their integrity by closing-out the world from their minds. By hanging an invisible veil in front of their eyes they did not see the fun of the other children and nothing could hurt their feelings.

The gocarts changed not only the situation of the disabled child but of the whole family. The dreams of many mothers had been to go for long walks in nature without having to push a heavy pram. Many families reported that they started to go for much longer and more frequent walks when the children could drive by themselves in their gocarts. Many parents also related that the children could take a more active part in the family life. They could do some gardening, do small errands etc. The whole family life was said to be more normalised.

The situation of the sisters and brothers was also affected. They were proud if having a brother or sister with a motor vehicle impressing other children. Moreover the demand to help the disabled child decreased when he/she could drive and play on more equal terms.

It was also interesting to note that the gocart influenced the relationships to neighbours and other persons in the environment. Not only the disabled child but the whole family was regarded as more "normal". Both parents and others found it easier to talk about the child´s disability when they could start a conversation by discussing the gocart. The "pity-syndrome" and the exaggerated consideration almost disappeared.

Effects on the intellectual development

Already when I planned the project I realized that the problems to evaluate the psychological testing would be tremendous. The number of children was small, tests of very young children are not always as reliable as those of older children, the commonly used tests have many shortcomings when used for children with physical disabilities. Besides we could not keep external factors under control for nearly 2 years, for instance the effects of physiotherapy, pre-school starts etc.

Even if we for several of the children could record progress in eye-hand-coordination and/or visual perception we can not draw the conclusion that this is effects of the gocart prescription. Many parents, though, reported that their children now were much more curious and fond of exploring the environment. Their possibilities to make their way in nature among stones, bushes, flowers, twigs etc. contributed to increase their sphere of experiences and they got opportunities to investigate new parts of the world all by themselves. Most likely this had an effect on the intellectual development, but how big we can not tell.

It is also a wellknown fact that all kinds of learning is much more effective if the child is motivated and has good self-esteem (Purkey et al., 1970).

Effects on the motor development

As regards the motor development no negative effects could be noted, only positive. Many parents and physiotherapists reported that the children´s head control, trunk stability and arm-hand function had become better from the training to get in and out of the gocarts. The children were so highly motivated that they surpassed themselves in their efforts. They all had their own style and technique. They did not become less motivated for physical traning. On the contrary several were more motivated because they were happier and more selfconfident. This is totally in accordance with my earlier experiences. If a child "chooses" to be passiv and "lazy" the reason is that the child has me so many and/or so great hindrances that it has resigned. These hindrances can be either physical or psychosocial.

Accidents and incidents

Only three incidents happened during more than a year. One child banged into a tree when he tried to run away from his parents and one gocart tilted when the child tried to go up the pavement at an angle. The third child was competing with his friends on tricycles. He made a too sharp turnover and tilted. None of the children were hurt in the incidents.

Conclusions

From this project and many others during my 16 years in this field I have learnt two things:

1) All kinds of habilitation work - medical, technical, educational etc, - should be based on a solid knowledge about children´s overall development and their needs and wants. Most likely many secondary effects of a physical disability could be avoided if we tried a little bit harder to integrate medical and technical factors with cognitive and psycho-social. Our knowledge of the positive and/or negative interaction between those factors is still rudimentary.

2) It is not the physical disability itself that makes people handicapped. It is the physical and social barriers in the environment that give rise to resignation, lack of initiative, low self-esteem and social isolation. Without motivation and selfconfidence it is impossible to be SOMEBODY!

A PROCESS FOR REHABILITATION ENGINEERING SERVICE DELIVERY

C. Gregory Shaw
University of Tennessee - REP, Memphis, Tennessee 38163 U.S.A.

ABSTRACT - A process has evolved enabling Rehabilitation Engineering Service Delivery Programs to provide their clients with appropriate technical solutions. The multi-step process involves careful consideration of client need and cooperation with client advocates before a technical aid is provided. By using the process selectively service delivery programs may enhance their productivity and better serve people with disabilities.

RÉSUMÉ - Un mécanisme permettant aux Rehabilitation Engineering Service Delivery Programs de fournir à leur clientèle des solutions techniques appropriées a été créé. Ce mécanisme à plusieurs étapes comporte une étude minutieuse des besoins de la clientèle et une collaboration avec cette dernière avant la fourniture d'une aide technique. En faisant un usage judicieux de ce mécanisme, les Service delivery programs peuvent améliorer leur productivité et mieux desservir les personnes handicapées.

Rehabilitation engineering strives to enhance the lives of the physically handicapped through clinical involvement in a total approach to rehabilitation combining medicine, engineering, and related science and technology. Service delivery is simply rehabilitation engineering applied to the individual. Although work done in the name of rehabilitation engineering is ultimately targeted to individual need, much of it seeks long range solutions to general categories of need. The Rehabilitation Engineering Service Delivery Program (RESDP) Component is structured to apply generalized solutions, techniques, and expertise to individual needs on a day to day basis. Service delivery, then, is interfacing of technology with the disabled person.

The human/machine interaction is complex. So too is the relationship between the disabled individual and the technical aid. Service delivery has evolved a step by step process which outlines the tasks required to make such a relationship a positive one.

REHABILITATION ENGINEERING SEATING SERVICE DELIVERY PROGRAM

Background History

The provision of custom seating has been a focus of the RESDP effort since the early 1960's. In 1962, the Ontario Crippled Children's Centre (OCCC) in Toronto, Canada initiated a Rehabilitation Engineering program to serve those individuals severely disabled as a result of thalidomide, a mutagenic drug taken by many Canadian women during pregnancy. Today children with cerebral palsy constitute the largest population served, with seating as a primary need. The OCCC pioneered seating technologies and evolved a process by which the technology could be effectively transferred to the individual. This process

Figure 1. Service delivery is the interfacing of technology with the disabled person.

follows the medical model of health care delivery in which client evaluation and assessment occur during a clinic staffed by medical, therapy, and engineering personnel. Many of the seating programs established since 1962 have adopted similar approaches.

A telephone survey of 14 RESDP's conducted in June 1983 polled the following seating programs for cerebral palsy children in North America:

* Rehabilitation Center for Children, Winnipeg, Manitoba, established 1968
* Rehabilitation Engineering Center Children's Hospital at Stanford in Palo Alto, CA, established 1974
* University of Tennessee Rehabilitation Engineering Program (UTREP) in Memphis, TN, established 1975

These programs, as well as many of the other RESDP's surveyed, have, in one way or another, adopted the OCCC's process. The philosophy upon which this process is built suggests that the clients's need be identified, defined, and resolved in a holistic manner, hence the heterogeneous clinic staff who explore needs in the context of the client's environment. The adherents of this philosophical approach insist that, without fully knowing a client's need, any implemented technological solution would be, at best, ineffective if not burdensome, or even hazardous. This holistic, problem-solving approach nurtures an interaction of different professionals in the health care field and in the community at large. The staff of seating programs thereby learn of their clients' related community resources and conditions. Equally important, the community learns what seating technology can and cannot do.

The process is a proven tool developed and currently used by most of the established seating programs. Its holistic approach helps avoid the inappropriate use of technology as well as the unrealistic expectation that technology is a panacea.

THE PROCESS

What follows is a practical methodology for providing people with effective seating systems or other technical aids. Although this process, as presented here, represents the product of UTREP Service Program experience[1] it contains major elements shared by other similar service delivery efforts. It's basic philosophy of humanistic design should shape the operation of all service delivery programs.

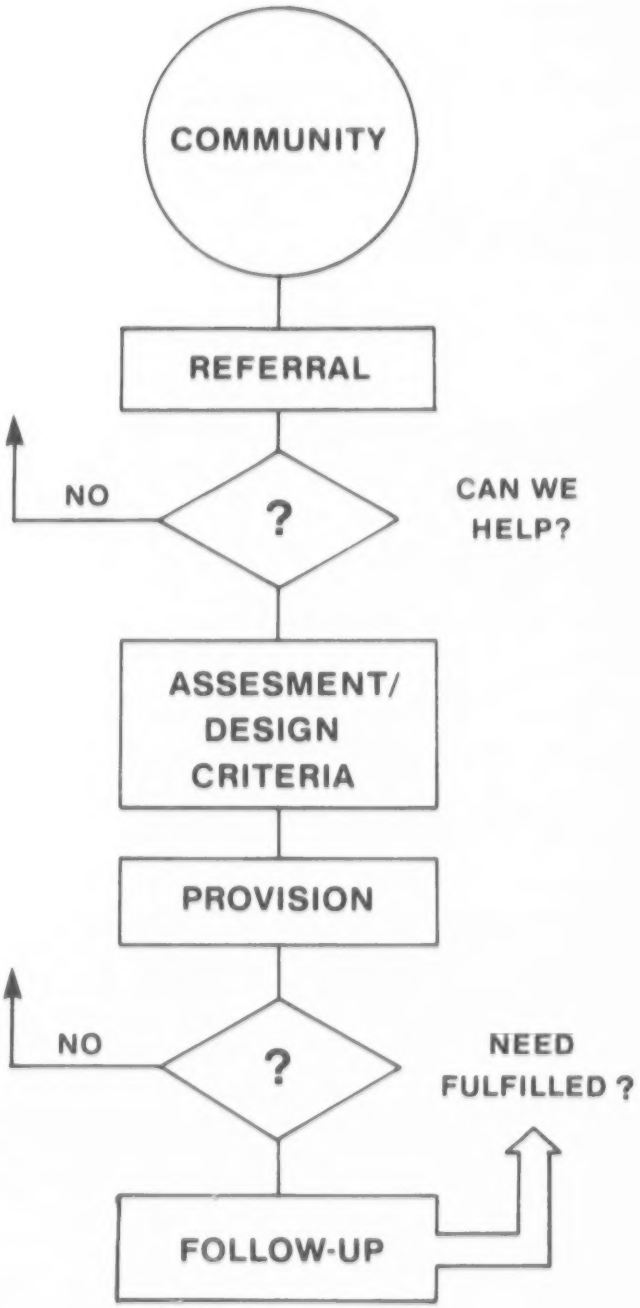

Figure 2. The process - a practical methodology for providing technical aids.

[1]Project Teach: A Model & Demonstration Project - Final Report (Memphis, TN: Memphis City Schools, 1978), p.7.

The Community

The "community", the needer group addressed here, for which this service delivery effort exists, is children with cerebral palsy. Because the children are often mentally retarded and/or unable to communicate verbally, their advocates - parents, teachers, therapists, doctors, and social workers, often express needs on their behalf. In the sense that advocates are representatives of the disabled child, they are also included in the "community". In the course of dealing with client advocates and the many organizations they represent, direct dealings with the client are often overlooked.

Magnitude of the Need

The consensus of the Rehabilitation Engineering professionals is that only a very small percentage of the community is receiving health care which incorporates technical aids such as specialized seating. Although there are many good reasons why this is so, the most significant roadblock is community ignorance. The RESDP therefore, must invest in ongoing community education. The education is a 2-way process. Not only is community awareness of technical solutions lacking but so is the RESDP awareness of the client's needs and community - the milieu of advocates, agencies, and institutions. Without such knowledge the RESDP is isolated and virtually powerless to provide solutions which will be warmly embraced by the community. Devices produced without active community participation will likely be locked away in a closet.

Service Delivery Program - Community Involvement: an interactive process.

Certainly community awareness is most important for the newer service delivery program efforts. Established programs must ensure that their knowledge of the ever changing community does not become outdated.

Demographics

Knowing how many cerebral palsied children there are in an area needing seating is invaluable for program planning. Unfortunately Cerebral Palsy is not a condition for which hospitals keep explicit records. Even if there was one easy source to determine the number of cerebral palsied children, statistics are rare that can map out a cerebral palsied population by levels of functional ability, i.e., ambulatory/ nonambulatory.

Local health departments, special education offices, pediatric hospitals, and developmental centers are all sources of data which, pieced together, may give an approximate number of potential clients.

The Health Care Establishment

Ninety-nine precent of all children with cerebral palsy are and will remain dependents of the health care establishment. Lengthy hospital stays, continuing therapy, and frequent out-patient illness are common. If, as is often the case, the child's family is in need of assistance to fund the required level of health care, the scenario is expanded to include extensive fund raising efforts in both the public and private sectors.

The health care establishment is an entrenched bureacracy fueled by massive spending. Rehabilitation engineering service delivery is a relatively new field, with limited financial resources. Developing adequate funding for RESDP technology therefore ensures the cerebral palsied child access to this service. The cooperation of a responsible and well informed pediatric orthopedist can constitute the influence needed to obtain recognition in the health care system and the necessary funding for the activities of the RESDP. The prescription of technical solutions is done in cooperation with the physician and is often necessary for access to established funding sources.

THE EDUCATION ESTABLISHMENT

The School System

Another pervasive force in the lives of cerebral palsied children is the educational establishment. Public Education has a federal mandate to provide the disabled child equal access to learning opportunities (Federal Law 94-142). Specialized seating, for example, is critical in supporting the non-ambulatory cerebral palsied child in an attentive posture for educational activities. Theoretically then, public education should actively procure such technical aids for their students. Sadly, however, funds to implement this ambitious mandate are meager and often channeled to other programs. Although a difficult task, the RESDP must seek to be accepted and nutured as a valuable resource by the school system. Developing such a relationship ultimately means active support by the school system to provide its students with needed technology. The effort however must start with individual students, their parents, therapists, and teachers; all of whom can help identify needs and monitor the performance of technical solutions.

The Family

Of all the institutions with which the Service Delivery Program interacts, the family is the most important. The parents (or guardians) ultimately must decide whether or not a technical aid will benefit their child. Carefully listening to parents and

supportively responding to their expressed needs requires time and patience. Families with cerebral palsied children often experience immense difficulties in obtaining appropriate services from both health care and educational establishments. The professionals involved in service delivery should realize that parents are also primarily responsible for acquiring technical aids for their children. This constitutes yet another burden for them. Their persistent effort to make headway in this bewildering red-tape world is to be supported.

Methods of Community Education

Once a RESDP feels confident that it understands the technical needs of the disabled children in the community efforts to educate the community can begin. Community expectations as to the benefits of technical services must be realistic. A RESDP should clearly define the client population with whom it is prepared to work. Setting realistic expectations avoids disappointment of clients and their families. The most responsible and effective education comes from actual experience with technical solutions in the community. Community word- of-mouth passes the final judgement on RESDP efforts. This is not to say that the programs should maintain a low profile. To reach and to help the many potential clients, community education, via media, in-service seminars, etc., can be pursued.

The community that the RESDP addresses is cerebral palsy children and their advocates. Because of community ignorance of technological benefits the RESDP must invest in an ongoing education program. The education involves an ongoing interactive relationship - the RESDP and the community learn of each other by working together. Moreover, without the support of established community institutions, the RESDP will fail in its efforts. RESDP community education programs should agressively promote appropriate technical aids without generating unrealistic expectations.

PROCESS SUBTASKS FOR THE INDIVIDUAL CLIENT

Referral For Technical Service

Referral for technical service is the community's expression of individual need to the RESDP. As soon as members of the community become aware that RESDP services are available, individual referrals will be made. Screening by RESDP staff should occur to ensure the appropriateness of the initial referral.

* Gathering Information

The child's advocates, their level of involvement, and their potential roles in regard to a technical aid should be identified. If the parent is the initiator of the referral he/she should be considered the primary advocate. If a social worker, teacher, or therapist (etc) suggested the referral, then this person should also be considered a key advocate. The first step in need definition is to gather pertinent data on the child: name, age, sex, address, diagnosis, prognosis, level of functional independence, etc. What are realistic educational and vocational goals? Step two involves defining the child's present environment. Does the child live at home or in an institution? What kind of educational program is he/she involved in? Who provides general medical attention? Orthopedic care? Does he/she receive regular therapy?

The above information is often collected by means of a referral form mailed to the initiator of the referral. Medical records and therapy history are also required to complete the information gathering.

Having reviewed the requested information, the RESDP can better interpret the client's technical needs. The RESDP staff decides whether or not they can address these needs. In some cases the child's physical condition indicates technical approaches beyond the RESDP's capabilities and referral to another agency is required. In other situations, a technical solution may be wholly inappropriate and the RESDP would suggest referral to appropriate health care resources.

Assessment and Design Criteria - The Investigation of the Referred Child's Capabilities & Clarification of Need

The goal of the assessment is to expand, clarify, and update the information gathered in the referral. During the Assessment the RESDP meets with the client and advocates. All interested advocates are encouraged to attend the assessment in order to provide complete information regarding the client's environment. Accessibility of the home and school is assessed. Who does the child often visit in the community and are the facilities accessible? How does the child travel to school? Answers to these and other questions will help the RESDP project the situation in which a technical aid will be expected to perform.

For a complete perspective of client needs, several advocates should be consulted whenever feasible. Each advocate may express a biased view of the child's needs and priorities. For instance, the orthopaedic specialist is primarily concerned with spinal deformity. The physical and occupational therapists address normalization of tone and increased function. The teacher stresses the child's ability to sit upright in class. The mother needs a way to transport her rapidly

growing child. All concerns are valid and the RESDP must attempt to incorporate these into the design criteria. Compromise must be possible where expected features are incompatible with others. All concerns and device expectations should be solicited at this point. Negotiated expectations are documented as a set of design criteria: a set of goals which the technical aid must achieve to be considered a viable solution.

At the UTREP-RESDP the assessment and design criteria steps occur during the preclinic and clinic process. At the morning preclinic the therapist, often with the engineer, evaluates the child's physical and functional abilities. Any orthopaedic deformities which might interfere with upright posture are noted. Environmental and educational factors are considered. Information from the family, teachers and primary treatment personnel is incorporated into the preclinic evaluation. Trials with specific devices may occur at this time. There are preliminary discussions with a social worker regarding possible funding sources.

During the afternoon clinic the findings of the morning evaluation are presented to the team which now includes the physician. A brief medical examination follows. The collected medical, therapy, and technical information, together with parent/child needs, guides the team to recommendations tailored to the client. A prescription is completed as well as medical dictation. The specifics of the design are decided at a post clinic session.

At the conclusion of the assessment, the design criteria for the client and his/her needs are specifically defined. Those needs appropriate for technical solution are itemized. Care is taken to communicate with the client and advocates the benefits they might reasonably expect from the prescribed aid. The next step, provision, endeavors to fufill these expectations.

Provision - The Transfer of Need-Fulfilling Technology

Provision is the hardware step in the process. The RESDP must translate the design criteria mandated by the clinic into a viable three-dimensional product. In some cases, commercially available technical aids might fulfil the design criteria. At other times the criteria may identify a commercial aid which, when modified, would fulfil the client need. If no commercial aid can be identified, then a custom aid must be fabricated. Technical aids therefore, can be classified as such:

1. Commercially available aids
2. Modified commercial aids
3. Custom aids

Commercially Available Aids

When an appropriate commercial aid can be identified this is the approach of choice. The primary advantage is that the time consuming and expensive task of product design, testing, and fabrication have already been completed. Seldom can an RESDP, no matter how extensive its technical resources, produce a prototype device as efficiently as can a commercial production facility. Additional advantages are as follows:

a. Many successful commercial aids have a history of clinical testing data and user experience.
b. Repair service under warranty is available should the inevitable breakdown occur.
c. Often it is possible to obtain aids for trial use before purchase.

However, the chance of finding a commercial aid tailored to a particular set of design criteria is slim. The universe of need is infinite and many disabled people need an individual design solution uncompromised by efforts to expand an aid's potential market size. Although well designed aids capable of meeting a specific need do exist, the task of ferreting them out is a difficult one. The information network for commercial aids is yet incomplete. Often a commercial aid will be identified which comes tantilizingly close to meeting the design criteria, yet, without modification, would compromise the client's function and/or comfort.

Modified Commercial Aids

Modified commercial aids are aids which, with modification, can closely fit a client's design criteria. Modifications might be very minor such as extending the length of a handle or the addition of a support strap. An extensively modified aid may bear little resemblance to the original. Depending on the extent of the modifications the advantages of a strictly commercial aid are forgone:

a. A certain amount of custom design and fabrication will increase cost and provision time.
b. Clinical data and user experience may no longer be applicable for the modified aid.
c. Modification may void the manufacturer's warranty.
d. It is difficult to test a modified aid before purchase.

Although one gives up many advantages this approach, the ability to more closely tailor to the client, is invaluable if standard aids represent too much of a compromise. In rare cases a technical solution demands a radical new approach

beyond even extensive commercial aid modification. A custom aid is required.

Custom Aids

The third option, a totally custom aid is one to be considered only as a last resort and only if the solution criteria demand it. In this approach the RESDP commits itself to the ambitious task of product design, testing, and fabrication. The aid must be taken through the total design process. Time and resources often unanticipated in project planning will be required. The cost of such an effort can rarely be borne by the client alone and is often subsidized in the name of research, RESDP self-education, and community service. In view of the high costs and expertise involved the RESDP should commit to producing a custom aid only after careful consideration.

The decision as to which approach the aid will take is usually the first step in the design process. The technical aid is often a composite system made up of several elements. For example, the RESDP's design team, a therapist, technician, and engineer, can design a seating system which includes custom seat and back modules mounted in a commercial wheelchair frame. Critical to the system's function are accessories such as the headrest, footrest, lap belt, chest support and communication tray. This system, a mixture of commercial and custom components, is considered a significantly modified commercial device. Once the aid, the seating system, has been so classified, the RESDP can better estimate the time and materials necessary to provide it, the total client cost, and potential funding source.

As is indicated in Figure 3 no matter what technical aid approach is chosen, the funding search is the next task facing the client and the RESDP. Depending upon the local level of financial support for technical aids, this task will range from insignificant to monumental. Most efforts fall in the later category with the aforementioned struggles with the health care and education bureacracies.

Assuming a favorable outcome of the funding search the RESDP must now provide the prescribed device.

PROVISION

Pursuing Commercial Aids

If a commercial aid can be identified care should be taken to thoroughly investigate the aid and the company providing it. Should the local dealer be unable to sufficiently answer questions with regard to aid specifications, warranty, optional accessories, delivery date, etc., the manufacturer should be contacted directly. Developing a productive working relationship with local durable medical equipment (DME) providers increases the possibility that the RESDP can more readily obtain an appropriate commercial aid. Good DME dealers are cognisant of the latest industry developments and often are willing to loan new items to clients for trial.

Developments in the last 10 years in commercially available specialized seating systems have been dramatic. Through judicious,knowledgeable prescription a wheelchair can become a truly tailored seating system. Techniques used to obtain accurate wheelchair sizes has been described.[2]

Pursuing Modified Commercial or Custom Aids

As per Figure 3, if the approach selected was to pursue either modified commercial or custom aids, the next step after the funding search leads to a technical source. A technical source is defined as an individual or an organization capable of modifying or producing a technical aid to a set of design criteria. Many DMEs and commercial aid manufacturers are willing and capable of modifying their own products. Other technical sources include: building maintenance personnel, volunteer crafts people, orthotics and prosthetics shops, high school shop classes, university engineering projects, and rehabilitation engineering centers. Some RESDPs have in-house technical services. No matter the nature or scope of the technical resource, the following steps should be followed:

1. Communicate design criteria to technical source - It is very important that the technical source have a clear understanding of what is to be accomplished. Because even minor aid modifications are subject to the pit falls of the trial and error design cycle, it is wise to provide the technical source with clear indications as to how an acceptable aid should perform. Without good direction a well intentioned technical source will waste many hours on unnecessary design.

2. Contract with technical source to produce the aid - Once both parties, having reviewed the design criteria, are in agreement as to the nature of the technical aid required, the RESDP and technical source enter into a

[2]Adrienne Bergen and Cheryl Colangelo, Positioning the Client with Central Nervous System Deficits: Wheelchair and Other Adapted Equipment. (Vahalla, NY, Valhalla Rehabilitation Products Ltd., 1982.)

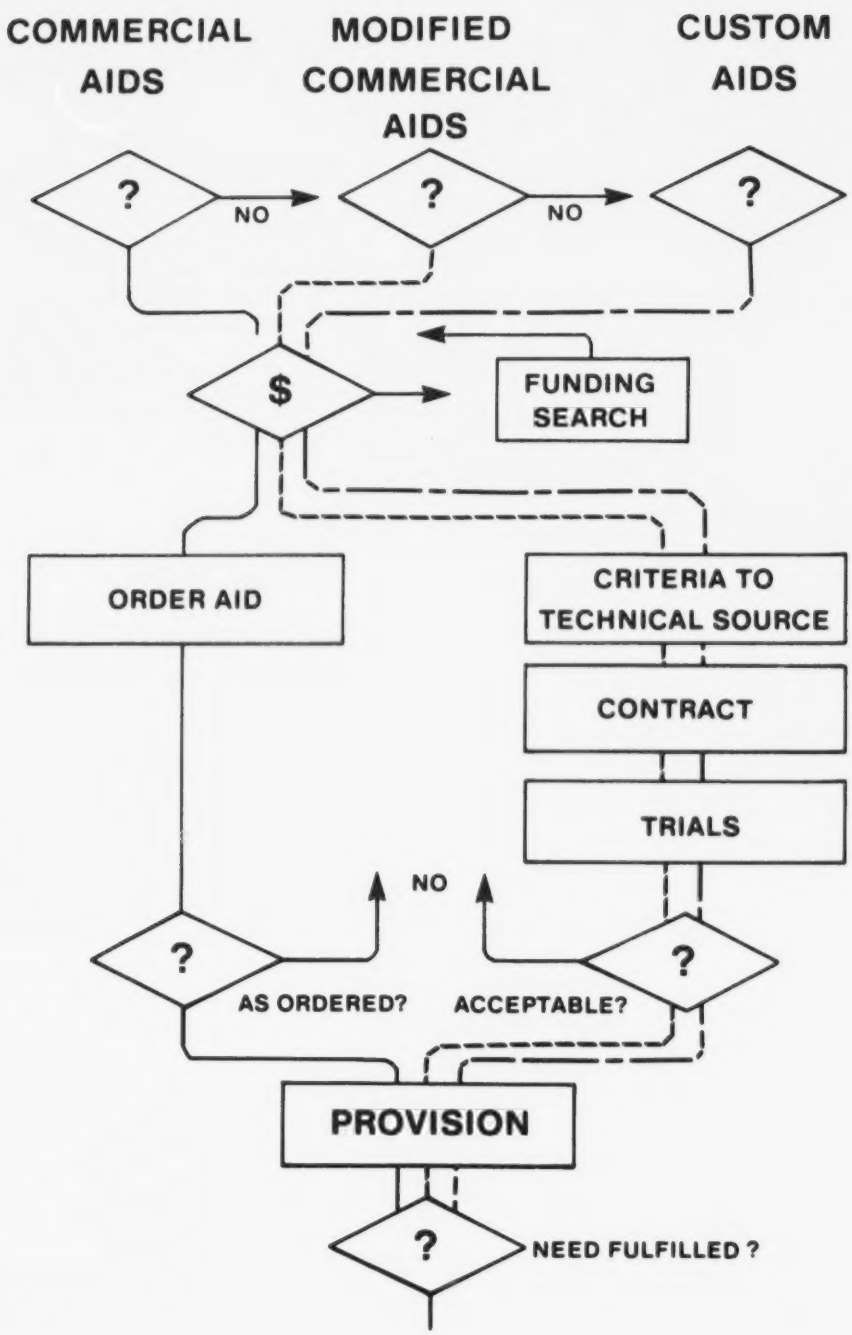

Figure 3. Process subtasks required in pursuing technical options.

contract. The contract should allow for periodic progress checks to avoid unnecessary waste of resources. Trials of the aid with the client will test its suitability. The contract should be firm in documenting aid delivery date, cost, and warranty.

Date of Provision

Once the technical aid has been fabricated the client should be scheduled for fitting and instruction. The client and his/her advocates should have a thorough instructional session dealing with both the technical and therapeutic aspects of the device. This ensures that the client and the device are compatible. The client and his/her advocates should not leave without practicing how to operate the aid and how to use it safely and effectively. On the date of provision the client should be scheduled for the initial follow-up visit.

FOLLOW-UP: CLOSING THE SERVICE DELIVERY LOOP

The follow-up is the last and one of the most important stages of the process. Agressive follow-up is mutually beneficial for both client and RESDP. No matter how careful the RESDP has been in designing the aid occasionally key factors are overlooked. Environmental considerations such as non-standard table heights or narrow doorways are commonly unanticipated. Mechanical failures must be dealt with as well as children's growth spurts. Functional capabilities and corresponding needs change. Medical conditions can change rapidly and render a new seating system inappropriate. Changes in academic programs can alter the original design criteria.

The most critical performance indicator to be monitored by the follow-up process is one of client and advocate acceptance. Does the client feel that the price paid in time, effort, and money is justified for the device? How well do the client's advocates work with the aid? Does the aid encourage or hinder their involvement with the client?

Through the follow-up the RESDP assumes an ongoing responsibility for each of its client's technical needs - a responsibility which does not end with the provision of a single aid. The service delivery process is an iterative one. If changing client needs require more than follow-up modification, the client is referred back to the assessment/ design criteria step. The RESDP follows a client until technical assistance is no longer needed.

The technical aid itself is the most effective educational tool available to the RESDP in its attempt to heighten community awareness. Positive feedback on individual aid performance, can give an accurate indication of overall community perception of technical aids and of the RESDP's efforts to provide them. A community which is led to unrealistically high expectations in technical solutions is difficult to satiate. In this situation the RESDP is encouraged to temper its advertising with practical community education. Ultimately, aggressive follow-up assures the community of RESDP commitment.

Discussion - The RESD Process in Day-to-Day Application

At first glance the process subtasks appear to be an enormous amount of work. Do RESDPs really follow such a regimen for each client seen? Yes and no. Yes, a good RESDP does indeed consistently use such a process as a guide to attain good results. No, one does not always pass through each step for each client. At the University of Tennessee RESDP care is taken to reach the goal of each subtask. All new referral handling is quite structured as is the assessment with its mandatory pre-clinic, clinic, and scheduled follow-up. The intervening steps; arriving at a set of design criteria, deciding upon a provision strategy and designing the aid, are all decision making tasks which tend to be relatively unstructured especially for less complicated client problems. For a 'simple' client, e.g., an 8 year old, spastic quadriplegic with no orthopedic deformities, the therapist often makes all these decisions during the course of the pre-clinic assessment. This is done only as a result of long practical experience on the part of the therapist.

Disparity exists between how problems are really solved and how problem solvers describe the way they arrive at workable solutions. Unfortunately, the service delivery process, as presented here, unlocks no profound truths of creative problem-solving. On the other hand, this imperfect design process is useful as a checklist.

At the University of Tennessee RESDP one tends to rely most heavily on the process for guidance when faced with a new challenge - a client with a new set of needs. He or she may come from an area in which we are not known so that we are faced with the task of community education. Additional referral information may be required for a rare medical condition. Assessment will include both a more comprehensive preclinic and clinic visit and perhaps an additional evaluation visit. The therapist will request a design meeting in which the physician's, therapist's, and engineer's input will produce a team decision. Because complex needs often requires a highly modified commercial or custom aid, the technician and engineer will have to be careful to design

the aid incorporating the various features specified by the team's design criteria.

The process assists both the individual and the group to check progress and avoid expensive waste of resources. Therefore, when it is felt that a client's needs are easily met, one tends to condense the time spent on decision making process subtasks. When faced with an obvious, challenging referral, one tends to be more conservative and rely more heavily on structured decision making. Having provided 500 seating systems for children with cerebral palsy, we feel confident that our experience justifies a certain amount of rapid decision-making which, of course, is an invaluable time and money saver. Our follow-up reports no significant problems specific to those technical solutions arrived at in this manner. The more experience a RESDP has, the more rapid decision making can be.

CONCLUSION

The Rehabilitation Engineering Service Delivery process is simply a way to use technology to solve individual needs. Though the concept is simple, the execution is often complicated by the difficulties of the human/technical interrelationship. The Rehabilitation Engineering Service Delivery process has evolved as a tool to divide this complicated task into subtasks.

The initial task involves interactive community education in which both the clients/advocates and the RESDP learn to work with each other. Once the community is aware that technical solutions exist, individual referrals will be made. The thrust of the referral and subsequent assessment tasks is the collection of pertinent data which will help clarify client needs. The technical solutions required are described by a set of design criteria. At this point the RESDP decides whether a commercial aid is appropriate or if a modified commercial aid or totally custom device is required. This decision defines the nature of the technical source needed to produce the aid. On the date of provision the RESDP carefully observes the client with the aid and provides instruction as to its proper use. Aggressive follow-up provides device maintenance and an ongoing reassessment/aid modification cycle for ever changing client needs. If client need changes significantly the follow-up refers the client back to the assessment step thus closing the process loop of evaluation - provision - evaluation. The follow-up, by monitoring community experience with individual technical aids, provides the RESDP with valuable feedback on its performance and indicates overall community perception of technical aid benefit.

The extent to which an RESDP uses the process on a day-to-day basis varies with its level of experience and percentage of challenging clients. The decision making steps, the design criteria, the choice of technical option, and device design are the most difficult for which to provide general guidelines. Depending upon the perceived complexity of client need, an RESDP may either welcome the inherent process structure or only use the process as a performance checklist.

The process presented here is intended to increase the efficient provision of technical aids for people with disabilities. The individual RESDP should consider the process, not as a rigid tasksheet, but as flexible guidelines to be followed at its descretion.

CHANGING PROSPECTIVES IN THE BASIC NEEDS OF THE HANDICAPPED

Jeanine Marty, Parent
Memphis, Tennessee U.S.A.

ABSTRACT - This paper deals with the effects of technical aids in dealing with the basic needs of the handicapped with emphasis on early placement and the role of the professional.

RÉSUMÉ - Cette communication traite des effets des aides techniques lorsqu'il s'agit de répondre aux besoins des handicapés, en mettant l'accent sur une affectation rapide et sur le rôle du professionnel.

The technology changes in the last decade have been vast if not awe inspiring. They have effected and altered the professional, business and personal aspects of all our lives. No one can say that technology has not touched their life in some way. To me the most exciting and challenging area for the change in modern technology has been in the area of Rehabilitation. I have observed this technology develop with active interest as it effects the future and life style of myself and my daughter. She is an athetoid cerebral palsy child. She is nonverbal and is effected in all four limbs. The development of technical aids for the handicapped has not only changed our family life but has allowed us to think positively about the future.

During the years surrounding the time of my daughters birth, I learned to my disappointment, that there was not much available to encourage or effectively help a cerebral palsied child. The role of the physicians and therapists was to enable the handicapped child to fulfill basic needs. Hopefully, the child would acquire basic skills such as feeding and self help skills. Perhaps independent mobility might be obtained or functional speech. The goal was to acquire basic skills or to make the role of the caretaker easier. The odds, however, were against the child ever progressing to the point of becoming a functional and productive adult. Because of her failure to respond to traditional therapies and the lack of common goals between family and professionals, my daughter faced, at best, a very bleak and extremely dependent future.

I find the term "basic needs and skills" interesting in that I question what they really are. What do we really need to perform as a functioning human being? Do we not consider the ability to communicate a basic need of ours? How about mobility? Do we not consider the ability to secure and maintain a position or job a necessity for not only our well being but our existence? Why then should it be any different for a handicapped individual. The advancements and innovations of the technology of technical aids in the area of rehabilitation have broadened and given new meaning to the definition of basic needs and skills. The goal of independence for handicapped individuals should no longer be unthinkable or unobtainable.

Though she was not aware of it at the time, nor for that matter was I, my daughter's road to independence began when we first visited the University of Tennessee Rehabilitation Engineering Program. She was eight years old but had not acquired the ability to do anything physically and she used her eyes as her only form of communication. Needless to say, this was extremely frustrating. We had not been exposed to any technical aids at this point. The Modular Plastic Insert (MPI) Seating System was the first aid that she received from the Center. I believe in all honesty that this was the key or the turning point for my daughter's future. Through observing my daughter and other children, I have become a proponent of the theory that handicapped children should be placed in a proper seating system as early as possible. This not only helps deter scoliosis but allows the child to be in a good position for communication and accurate evaluation of body control. Once my daughter was seated properly and her arms and legs comfortably restrained, it became obvious to the professionals that she might have enough foot or head control to effectively activate some form of communication device. I believe that the provision of technical aids should be considered in conjunction with traditional therapies at a very early age. The two approaches will be complimentary and if traditional therapies are not successful no time will have been lost.

Communication is a basic need! As each child is different, a form of augmentative communication must be chosen or adapted to meet their specific needs. Given a means of communication, a handicapped child will not only be able to express their daily needs, but they will advance more rapidly in school. The frustration level for the child and family will decrease. The childs inner self will emerge and a feeling of self esteem will be experienced on a daily level. I am sure you will agree with me that when one feels good about themselves, it carries over into every aspect of ones life. Communication systems with children must be started in a simple form and progress to a more complex and sophisticated system to be positive and effective. In applying this concept to my personal experience, the professionals working with my daughter chose first the Etran system to capitalize on and develop further her eye placement, spelling, vocabulary and communication skills. When she obtained proficiency on this system the transfer to a light sensor on her glasses was made with relative ease.

My daughter's goal of total independence may never be reached. Only time will tell us this, but unlike the first years of her life, time is now working in our favor. Each handicapped child or adult should now have a more positive outlook towards their future independence if joint effort has been made by the patient, professional and family to work toward the implementation of a long range goal by the effective us of technical aids. You have the education and hopefully the imagination to help the handicap achieve. Don't limit them by not having the insight to know that independence, communication, and mobility are basic needs. If rehabilitation begins with the child; if simple technical aids are started early and advance as the child progresses; the chance of these handicapped children becoming productive adults will be greatly increased and the population of handicapped adults needing rehabilitation greatly decreased.

My daughter is sixteen now. She spent almost the first half of her life in total frustration. This put an enormous strain on the home environment. In reflecting back it almost seems as if I am speaking of another family. We were all, her father, her sister and myself, handicapped by the frustrations of her handicap and I foresaw the future as an unwanted enemy. The last eight years have been a reverse of that trend. Technical aids in our lives have made the difference. These changes did not come overnight but starting with the innovation of the seating system she has advanced through the years to operating a communication device which also has the ability to provide her with independent control of her wheelchair. She has been steadily advancing in school and has developed friendships through ease of communication. These changes in her have of course effected the home life. The tension and frustration level are low. Although her sister and I are still her main caretakers, she is not as dependent on us for her total self esteem and productivity. The excitement of technical aids is that they are constantly changing. Within the next year, she will be receiving a totally new system. She will be the recipient of a Minspeak Communicator which will also provide the mobility control of her wheelchair. An environment control system will also be added to this system. With this additional equipment she takes another step towards independence. I smile with inner satisfaction when I hear her speak of her plans to enter college upon graduation from high school. I remember our early prognosis and frustrations and what a total difference it is to be discussing career plans with her. But one must remember that these very normal goals of a sixteen year old girl have only been thinkable due to the advancement of technical aids and the professionals who have not lost sight of her ultimate goal of independence.

One last note. In a recent conversation with my daughter, she informed me that she wanted to start a savings account. When questioned if she had something special she was saving for, she smiled with a glint in her eye and printed out....a car. We both laughed. Take with you the lesson I have learned from my daughter, Lainey. Don't limit your thinking for the handicapped. They want it all.

LIVING INDEPENDENTLY WITH TECHNICAL AIDS

Beryl Potter, O.M.C., President
Scarborough Recreation Club for Disabled Adults, Scarborough, Ontario Canada M1G 3M4

ABSTRACT - The paper reviews the need of technical aids and devices for disabled persons. How necessary it is for the correct aids to be used at the right time; and the importance of self-help, acceptance and co-operation between therapists, doctors -- and clients.

RÉSUMÉ - Le présent mémoire passe en revue la nécessité de mettre au point des aides techniques et des appareils pour les handicapés; le besoin impérieux d'employer les aides appropriées au moment opportun; et l'importance d'entraide, d'acceptation et de coopération entre thérapeutes, médecins et clients.

The onset of this paper may appear to many people that I personally only accepted the use of and learned to live with technical aids and devices since a simple accident 18 years ago. This however is only partly true.

As a result of slipping on a piece of cellophane paper in 1965, blood clots formed behind the knee developing into Thrombo Phlebitis. It was during the following five years that I lost both legs, right arm and the sight of one eye.

This of course was an extremely traumatic time for me, as naturally would be for anyone. I had none or very little knowledge of what a technical aid could mean to a disabled person's life. In fact, I don't believe I even knew what they meant exactly or to what extent they could be used.

I do know however that I was not alone in my ignorance. As human beings we so often take the most common things in life for granted, and the very thought of a non-disabled person being told that they had depended upon adaptive aids and assistive devices all of their lives, would come as a great shock to many. Yet, if it were not for the use of aids and devices from the day they were born, we would still be living very primitive lives.

Was it not the cave man who carved utensils from animal bones to assist them in eating, such as spoons, and spears and knives for hunting food that was served in bowls molded from mud or clay. Combs from bones to assist in one's grooming, or round stones smoothed and bored for wheels to assist in transporting. Animal skins stretched and dried for clothing to assist them in keeping warm and for carrying life giving water supplies over barren territory.

The list is endless, and everything was vital in assisting a person to live independently.

Technical Aids or assistive devices are frequently used as preventive measures - such as seat belts, steel capped boots, helmets and safety glasses for industrial workers, etc.

Corrective aids used at many childbirths or in the early years of childhood, have prevented many surgical procedures and heart break for parents besides avoiding more serious disability later on.

You are no doubt wondering by now why I am wasting the time to write about things that are common knowledge. The problem is however, that we are not conscious nor capable of connecting ourselves personally as having the need for such devices until it is often too late, and it becomes necessary to turn to the more highly technical aids in order to live independently.

It is a sad way to learn, but is anyone really aware of the exquisite feeling of freedom when a technical aid can all of a sudden give back the ability to move, walk, talk, hear, see, breathe; or know the terrible fear and agony of being left alone in case anything goes wrong and you are in danger.

Since my accident I have learnt to use many aids that have been household items in almost all homes for decades. Some only require minor adjustments, for example -- the foot pedal of a sewing machine now sits on the table in front of the machine and is used by the stump of my right arm enabling me to make all my own clothes, (something I had never been able to achieve previously). A simple 15 inch spring with a magnet on the end used by mechanics to retrieve nuts and screws fallen into the engine, now sweeps my floor to pick up pins and needles; it also helps me to lift cans of soup, fruit or vegetables from a high shelf. A long crochet hook held under my stump enables me to crochet. A belt with a Shetland buckle used for hundreds of years in the Shetland Islands will hold various sizes of knitting needles allowing the

ladies to knit beautiful garments for twice as many hours by using only one hand at a time. This adaptive device enables a stroke victim as well as myself to knit also.

A counter board with stainless steel nails will hold vegetables, meat or bread therefore requiring only one hand for cutting, etc. A feather duster will reach places impossible to reach from a wheelchair.

High Tech items are becoming more and more of a household item for disabled persons, i.e. hands free telephones, large key or mouth operated typewriters. Computers are creating home employment. The Phonic Mirror Handi Voice allows thousands of non-verbal persons to communicate, even over the telephone. It is possible now for a quadriplegic to live at home and be almost entirely independent with the use of an Environmental Control System. This system may be expanded upon to accommodate a persons need and is capable of handling almost every electrical switch in the home, from answering the doorbell to turning a light on or off.

Technology today is making it possible for even the most severely disabled to live almost independently with some human assistance or attendant care.

The many different types of wheelchairs and mobile devices such as automobile controls are allowing the freedom of independence, both economic and leisure to thousands of persons whose only chance of survival was once institutionalization.

Problems concerning highly technical aids and assistive devices still exist however. Many could be avoided with understanding and kindness, while others will take much more co-ordination and government sensitivity.

The cost of these aids, especially the highly technicals types are more often then not, entirely out of reach for a person on a limited budget, and very often for those in the high salary bracket also, due to their exorbitant cost.

Knowing these aids are available and that they could make the difference between independence and total dependence can be extremely frustrating and demoralizing, but until the costs are adjusted or assistance is available for those needing such aids, little can be done.

The use of technical aids or assistive devices are extremely important to the health and rehabilitation of disabled persons. It is equally important that the right aid is introduced at the appropriate time; that is for use rather than for looks alone and/or pity. All to often a device is provided by well meaning parents or family members when a less highly technical aid would be more suitable.

If a more extensive training programme for therapists were available in the use of the correct devices, and if some doctors and social workers could learn to be more sensitive to the real needs of a disabled person, many problems could be solved. Help and co-operation of the disabled themselves in assisting their therapists and doctors could be of great help also. Everyone would like to be in the position to drive a Cadillac, but most people have to settle for a more economic car. A disabled person must learn that it is more realistic and important to be comfortable with their devices.

To purchase a wheelchair that is too big or too heavy is the fault of both the user and therapist. It must be remembered that they have to sit in it for many hours and use it for many different reasons.

Being fitted for a wheelchair is like being fitted for a pair of shoes; they must be comfortable and realistic. For instance, we would not purchase high heels to go hiking, or work boots to go dancing. Wheelchairs, like shoes, can result in many unnecessary back problems if wrongly fitted.

Almost all disabilities, regardless to the type of accident or disease that causes them, differ. This is also true with many aids and devices as will be shown in the following cases. Names used will be fictitious for obvious reasons.

CASE #1

Jane, suffering from Cerebral Palsy although in a manual chair, was able to stand and walk on crutches. This enabled her to work around the house and keep her muscles strong. Her friend, Mary however was much weaker and it was necessary for her to use a powered wheelchair. Jane found it difficult to keep up with her when they were outside and complained to her father about this, who feeling guilt and pity, purchased a powered chair for Jane also.

Within six months the manual chair was used only if someone was available to push it, with the result that Jane became too weak to use crutches any longer. What strong muscles she had previously, deteriorated and wasted. She gained a great deal of weight; became sullen and withdrawn; lost Mary as her friend and has no will to be involved.

To promote a person, especially a child or teenager from a manual wheelchair to a powered one too soon or unnecessarily, can be damaging to their attitude and outlook on life.

CASE #2

Little Johnny with Spina Bifida is an extremely intelligent and active child who attended nursery school at 2½ years of age. His standing brace and walker did not bother him, but he wanted crutches like his 4 year old friend at school. Although Johnny's mother constantly asked the therapist and doctor that he be allowed to have them, she was told that he was far

too young to use crutches. The result was that the 4 year old was often left without mobility as Johnny would borrow his crutches and take off with them.

Finally convinced after complaints from the teacher, Johnny was allowed to have his own. The right time to use an assistive device often rests with the persons attitude and ability to adapt, rather than with statistics.

CASE #3

Keith, a quadriplegic and aphasic young man of 16 years was considered to be beyond rehabilitation, spending the following 10 years in an institution. Befriended by a young lady and her mother who could not accept such a prognosis, determined to change his life with the use of technical aids, love and understanding.

Their house was sold for a more accessible apartment; their car traded in for a van. A fund raising drive allowed the purchase of Phonic Mirror Handi Voice, a powered wheelchair, a hydraulic lift for the van, and a bathtub hoyer plus another for general transferring purposes in the home.

The result is that Keith attended night school for computer programming. He now feeds and shaves himself, writes articles and composes poetry, paints and sketches, and communicates with other people throughout the world by recording through his Handi Voice on cassette tapes.

The voice synthesizer, which is basically memory work would naturally not be suitable for all non verbal persons, in which case a Bliss Board may be used

CASE #4

Michael, a black gentleman, also an amputee was being measured for a prosthesis by a therapist in a small town location. To speed up the procedure, the measurements were given over the telephone. The limb arrived; the measurements were correct but it was also white. A simple but very serious mistake on the part of the therapist.

The colour of the limb was easily rectified, but the damage to Michael's dignity could have been irreparable.

A triple amputee, like myself, could possibly be fitted with artificial limbs but because my amputations resulted through circulatory problems, the straps needed to hold the limbs in place could have been a danger to my circulation.

Although I do own a triple amputee manual wheelchair, it is used only for emergencies because the downward pressure of my left arm will cause swelling and pain. Consequently, it is necessary that I use a powered wheelchair.

With the knowledge in technology becoming greater every day, there is little reason to doubt that within a few years disabled persons may be given the opportunity to possibly live as independently as non disabled, regardless as to the type of disability.

We must remember however, that technology alone cannot change attitudes. There is not a thing in the world that will change a persons life unless they learn to accept themselves for what they are capable of doing, rather than what they cannot do.

My closing message to all people is to appreciate life. If highly technical aids are unnecessary in your life, be thankful and do everything possible to prevent them from becoming so. If they are necessary in your life, then use them wisely and with dignity.

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